VOL. 3 NO. 2 JUNE, 1916

PROCEEDINGS 36TH YEAR

JOURNAL
OF THE
AMERICAN WATER WORKS ASSOCIATION

PUBLISHED QUARTERLY BY THE

AMERICAN WATER WORKS ASSOCIATION

AT 2419-21 GREENMOUNT AVE., BALTIMORE, MD.

SECRETARY'S OFFICE, 47 STATE ST., TROY, N. Y.

Entered as second class matter April 10, 1914 at the Post Office at Baltimore, Md., under the act of August 24, 1912

JOURNAL
OF THE
AMERICAN WATER WORKS ASSOCIATION

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THE TYPHOID TOLL

By George A. Johnson

Certain cardinal facts stand forth in opening a discussion of the significance of typhoid fever. First of all, let it be clearly understood that there is no question of its being an entirely preventable disease. Second, that all typhoid is caused by taking the typhoid germ into the mouth. And, third, that typhoid fever in America is the chief disease conveyed by impure food and drink.

These premises stated let us go a little further in the line of elaborating on these basic facts. Since the disease cannot be contracted naturally without taking the specific germ into the mouth, and since the manner in which this act is commonly performed can be said to be associated almost exclusively with the consumption of typhoid infected food and drink, it follows that to eradicate the disease involves only the exercise of really simple measures of precaution, which, in the concrete, are to see to it that the food and drink be pure, or made pure, and kept pure until consumed. Public understanding of this need is, of course, in the ideal sense, imperative, but when once the typhoid scourge has been placed under control, it is possible for public health authorities to prevent the reëstablishment of its sinister influences on the public health, in spite of the ignorance, selfishness, or almost unbelievably complacent tolerance of the public itself.

It is not for a moment denied that to effect this idealistic result is an undertaking beset with tremendous difficulties. The public is not to be blamed unqualifiedly for individual or collective responsibility in the maintenance of this filth disease among human kind. Education must be forced upon the public by those qualified to teach; public health officials must be given wider power through more exact and far-reaching laws aimed at the destruction of the roots of this filth-sustained plant; and ample funds must be appropriated to carry through the work. The vital capital needlessly dissipated by the typhoid scourge in this country amounts each year to not less than $150,000,000, yet the combined annual appropriations for all the health departments of the cities of the United States amount to less than 30 cents per capita, or not more than $15,000,000. This fund is made to cover the expenses of work on infant morbidity, inspection of school children, laboratory and dispensary service, tuberculosis, and for educational and publicity work, and this sum is clearly inadequate for the efficient prosecution of tuberculosis work alone. In New York City a very large share of the expense of such work is borne by the Department of Charities. Probably not 10 per cent of the health department funds are devoted to holding typhoid fever in check; the prevention fund, if you like. Such an amount would be equal to 1 per cent of the loss suffered through failure to exercise adequate and efficient measures of prevention.

Public health officials realize this unsatisfactory state of affairs, but if insufficient power is given them under the law, and if they are hampered by lack of funds and competent helpers to do the things they know are necessary, who is to blame? The annual budgets, with very few exceptions, are made up by officials who sense but dimly the responsibility they shoulder when they cut the health department appropriations to the very quick. Ignorance on their part of the reasons why heavy expenditures for disease prevention are justified is largely responsible for this; and the average health official realizes only too clearly how wellnigh impossible it is to obtain for his work even a reasonable approximation of what his department could make very good use of. The soundest argument for larger appropriations to place before the arbiter of state and municipal financial expenditures is a statement of what preventable disease actually costs in dissipated vital capital. A city of 100,000 people, with an annual typhoid fever death rate of twenty,

suffers an annual loss of vital capital from this disease alone amounting to $150,000. In view of the indisputable fact that typhoid fever is preventable, the actual loss of this amount of vital capital through failure to provide sufficient means to effect such prevention, is mighty poor financial management. And yet dozens of cities do experience as great, or an even greater proportional loss in this way each year. The present day typhoid toll of New York City, expressed in lost vital capital, amounts to $4,000,000 annually.

If the adjuster of a municipal or state budget were knowingly threatened with illness, or one of his immediate family so affected, he would not hesitate to spend any reasonable sum of money to defray the cost of obviously necessary preventive measures. Life insurance certainly is popular, and it is not to be supposed that the officials of city and state finance departments are immune to the persuasive arguments of life insurance agents. This is protection against the effects of disease, nevertheless such officials wield an energetic blue pencil when they reach the health department item in the annual budget. They cannot see the return of good to the public, even though they realize the protection afforded to themselves and their families from their life insurance, or they would not pay the premiums.

Until one near and dear is attacked by typhoid fever its repulsiveness and fatality are not seriously viewed. To an individual who has it, typhoid fever is no joke. To those who have never experienced it personally, or viewed its effects, it is often dismissed metaphorically with an airy wave of the hand, as being largely one of those children of the imagination of sanitarians who derive profit from the preaching of the doctrine of prevention, and who endeavor, through the exercise of meretricious reasoning, to deprive the public of the comfortable, sovereign privilege of insanitary habits.

The general public, eliminating, of course, those individuals who have learned by sad experience, rarely gives a thought to the possible disease bearing properties of the two essentials to human existence, drink and food, unless these commodities actually are repulsive to the senses. There is tacit knowledge that such matters are controlled by some mysterious, yet real, authority, hence blind confidence impels the public to take things as they come, and we well know with what disastrous results sometimes. Yet how can the public protect itself where individual ignorance obtains,

and when the health authorities cannot, or do not, exercise proper vigilance in preventing the delivery to the people of impure water, milk and other foods?

The traveler steps aboard a fast express with no concern except a desire that his accommodations be satisfactory, and that the train may arrive on time, yet his life and those of hundreds of fellow travelers are in the hands of the engine driver and other employees of the railroad company. One lapse of vigilance, one disobeyed order, one signal ignored, and those lives are dashed into eternity, and the maimed bodies of those who escape death are sentenced to a lingering life of pain. And it is noteworthy that where one passenger is killed in a train accident one hundred are killed by typhoid fever. Every normal individual freely walks the streets of his city, and repeatedly, day after day, steps upon shaky and rattling sidewalk gratings with never an apprehensive thought of their possible instability. This is but another exemplification of the customary blind confidence of the public in its officials, and it is generally admitted that municipalities are not so efficiently managed as privately owned companies, although this statement is by no means to be taken as a gratuitous condemnation of municipal ownership.

Twenty millions of people in the United States are now being furnished with filtered water at a cost not exceeding $8,000,000, or 40 cents per capita, per year, and in these cities having filtered supplies the water borne typhoid fever has been practically eliminated, as reliable statistics abundantly prove. Inexpensive as water purification is these people are spending more money for that alone than they appropriate for the work of prevention and public treatment of all diseases, whether water borne or not, and it is not to be forgotten that out of the public health fund comes a considerable expenditure for work in the line of the conservation of purity of public water supplies.

The results of water purification always show a big balance on the right side of the ledger. Where one dollar is spent for pure water many dollars are saved in the form of vital capital through the prevention of sickness and death. If a community of 19,000 people spends each year 40 cents per capita for filtered water, and thus each year prevents a single death and the attendant cases of illness from typhoid fever, it will come out even financially, and increase its self-respect into the bargain. In Pittsburgh, to cite

a well known example, the adoption of water filtration has saved over 600 lives, 9000 cases of typhoid illness, and $4,500,000 in vital capital annually.

Three hundred thousand persons suffer annually from typhoid fever in this country, and 20,000 die of it. This means that in the course of a decade one person in every 33 contracts typhoid fever by taking into the mouth germs discharged in human urine and feces. Of those who recover a substantial number die later from other causes leading out of a depleted vitality. Still others never completely recover from its effects, and, although they may live to old age, their usefulness has been materially curtailed. To give for each human life lost through typhoid fever an average value of $3600, and for lost wages and medical attendance $200 per case, the present day annual typhoid toll in the United States amounts to $130,000,000. It would seem that the influence of depleted vitality in the case of typhoid convalescents resulting in earlier deaths from other causes, and depreciation of usefulness through the years of remaining life, should be given some expression of money value, and if for this even $75 is allowed for each typhoid convalescent the final result is $150,000,000, as representing, in terms of dissipated vital capital, the annual typhoid toll paid by the citizens of the United States each year. The compulsory tribute paid by the Athenians to the Minotaur was considered noteworthy, but by comparison this mythical sacrifice for a fixed purpose sinks to insignificance beside the real and needless sacrifice of the present day in this country to a force which derives its power from such unenviable sources as lassitude, ignorance and filth.

Whose is the responsibility? Who can be blamed for permitting typhoid fever to exist and thrive in this enlightened age? Is it the national government, the state governments, the municipal governments, or the people themselves?

There is no law prohibiting the consumption of impure water or food unless the consumer deliberately contemplates suicide. The average state cannot, or, to say the least, has not thus far been signally successful in so doing, force a city within its boundaries to cease allowing impure water and food to be furnished to its citizens. The national government has no control over health matters in any individual state. Each state is a power within itself, in this regard, and in a very large measure each city also, and each individual citizen as well.

The national government has a certain sort of control over boundary waters, but here its effect on the public health is virtually negligible, and otherwise, at the most, it exercises but a paternal influence in questions of pure food and drink. The state health departments, with their limited funds and power, do much good in encouraging the purification of polluted water supplies, the sanitary disposal of sewage and refuse, the prohibition of adulteration of foods, and, largely by moral suasion through the admirable medium

TABLE 1

Estimated value of human life and of lost wages and medical attendance in cases of typhoid fever

AGE	PER CENT OF DEATHS FROM TYPHOID FEVER	TOTAL DEATHS FROM TYPHOID FEVER	ESTIMATED VALUE OF HUMAN LIFE
years			
Under 5	5.5	1,100	$400
5 to 9	6.0	1,200	1,800
10 to 19	20.5	4,100	3,600
20 to 29	29.0	5,800	5,000
30 to 39	17.0	3,400	4,200
40 to 49	10.0	2,000	3,600
50 to 59	6.5	1,300	3,000
60 to 69	3.5	700	1,200
70 and over	2.0	400	—
Totals and Averages......................		20,000	$3,600

For each typhoid death count fifteen cases. Medical attendance, nursing, medicines, etc., taken at $100 for each case of typhoid. Lost wages for two-thirds the cases with ages from ten to sixty years at $14 per week for twelve weeks (representing the "workers" but not necessarily the "wage earners") averages $100 each for all cases. Then add $75 per convalescent case for depreciated vitality. The sum total vital capital loss from one typhoid death is $7500.

of education, exert a generally benign influence in other lines of disease prevention. The city health departments, having a narrower field to cover, probably accomplish more visible good, and when such departments are in the hands of competent officials, and when the available funds are an appreciable fraction of what they should be, and where the local officials have the sympathetic coöperation of the state authorities, the results accomplished have been all that reasonably could be expected.

We elect our state and local officials, or at least some of us labor under the fond belief that we do, and they in turn appoint our health officials. The amount of money which these officials are able to obtain for the maintenance of their departments often depends, sadly enough, not so much on what happen to be the needs of the department, as on the persuasiveness of the head of the department.

In the last analysis, education respecting health matters is the light which eventually will lead us out of the insanitary wilderness. Almost every year sees an improvement, but except in the field of water purification, wherein the past fifteen years have seen stupendous advances, other lines of disease prevention work, allied to impure foods, with some exceptions in the case of milk, have not advanced a fractional part of what they should; and lack of public realization of the controlling conditions is chiefly responsible for this deplorable state of affairs.

The annual budget is usually scrutinized with the temper of the public in mind. How often we see published the vainglorious statement that "The tax rate of Utopia will not exceed so many mills this year." This is a plea for public recognition of the care with which the city officials are spending the people's money. To keep the tax rate down how many lives are uselessly sacrificed? On what important governmental department appropriation is the blue pencil used more freely than that of the department of health, unless it be a public works department appropriation for water purification? Can any reasoning mind fail to see that when once enough money has been appropriated to the health department for the proper furtherance of measures of prevention against disease, each year should see this appropriation maintained in proportion to the increase in population?

The department of publicity and education of the state board of health of New York heads its bulletins in the following manner:

"Public health is purchasable. Within natural limitations any community can determine its own death rate."

Every individual is supposed to have a wholesome fear of disease, and at least some regard for its fatal possibilities, therefore if the campaign of education were carried far enough individuals would be advised how to avoid disease and preventable death. No better public educational system has been devised that does more good than the health exhibits prepared for public study, and even some-

times carried, by the medium of special cars, to the very homes of the people. To protect the health of the public gentle persuasion must first be given a trial, and, finally, if that is unheeded, compulsory observance of sanitary customs must be resorted to.

Sanitation through the agency of publicity campaigns is the best medium we have. But it is another case of the horse and the water. The most inspiring and convincing arguments may be spread on paper and widely distributed, but as a class the people will not read them and be instructed. To follow the instructions set down in these bulletins means some sort of curtailment of the personal license which the American public regard as one of the chief benefits of a free country. The line between liberty and license is nowhere so loosely drawn as in this country.

The widespread enforcement of the anti-spitting law gained favor, not so much because the rank and file of the people really believed that disease was spread in this manner, as for the reason that the act and effect of its practice were repulsive. Individuals, and not classes, are affected by this law and in public obey it fairly well, yet the same individuals sewer from their cesspools, and cities discharge their huge volumes of sewage, direct into waterways from which other communities draw their water supplies. There are just as strict laws governing such violations of one of the most elementary laws of nature, yet the individual violator is almost never punished, and the collective violator, while sometimes brought to the bar of justice, usually is discharged with a naughty boy reprimand on the giving of promises to remedy the evil, and in which promises, even as he gives them, he ofttimes makes mental reservations to keep only when he can no longer avoid keeping them.

Several centuries ago Samuel Butler had a clever idea of health Utopianism, and obviously meant what he said even though his views were expressed in a clearly satirical manner. Writing of his visit to the mythical country Erewhon, he records his impressions that in that country if a man contracted a disease, or failed bodily before he was seventy years old, he was adjudged a criminal and dealt with accordingly; whereas if he merely forged a check, fired a house or did any of those things which, by us, are considered criminal, he was taken to a hospital and tenderly cared for at the public expense, the assumption being that he was suffering from a severe fit of immorality. He was visited by his friends who in-

quired with great solicitude how it all came about; what impelled him to forge the check, set fire to his neighbor's house, or what not, and the whole problem was thoroughly threshed out without reserve.

Butler records his experiences in a court in Erewhon where he saw prisoners being sentenced for injuring their health. To one particularly hardened criminal the judge said:

> Prisoner at the bar, you have been accused of the great crime of laboring under pulmonary consumption, and, after an impartial trial by your countrymen, you have been found guilty. This is not your first offense; you have had a long career of crime. You were convicted of aggravated bronchitis last year; and I find that, although you are now only twenty-three years old, you have been imprisoned no less than fourteen times for illness of a more or less hateful character.

In Erewhon, it appears, if a man permitted his health to run down he was counted a greater criminal than the man who merely burned down his neighbor's barn or stole his cattle. His health was a part of the state's assets, and if he allowed it to deteriorate he defrauded the state. In a broad sense why is not this viewpoint entirely reasonable? If it should become the custom to handle health matters in this manner a tremendous impetus would be given to all lines of preventive medicine, practiced by the layman as well as the professional sanitarian.

The prosperity of a nation depends upon its productive power, and it hardly can be considered good business policy to submit to a depletion of that power many times in excess of the cost of its conservation, and resulting from the failure of the public to realize the truth. In the interests of the nation it is imperative that they be brought to a sense of realization of it, and that if they cannot or will not be taught, the interests of the nation demand that country-wide changes in the present modes of insanitary living be forced, and the public be made to understand that in some things they must be guided by others without asking, or perhaps reasoning, why.

FACTORS TENDING TO SUPPORT THE PERSISTENCE OF TYPHOID FEVER

A significant fact disclosed by a study of the mortality statistics of the United States is that in rural districts, that is, where the population of communities is less than 2500, typhoid fever is more prevalent than in urban districts, although the combined mortality

from all causes is greater in cities. Occasionally this rule may not hold, as perhaps in the case of New York for last year, when the rural combined death rate of New York State was in excess of that of New York City; but generally it does.

What, then, are the reasons why typhoid fever is more prevalent in rural districts than in urban districts? To the sanitarian this is no mystery. In rural districts the individual is a plenary power unto himself. In small communities the appropriations made for disease prevention work are trifling, and to attempt by innocuous persuasion the observance of regulations looking to more sanitary modes of living, and thereby summarily alter the practice of customs observed for generations, is sometimes sufficient to arouse antagonism on the part of the individuals affected pronounced enough in itself to preclude the establishment of different, and better, practices, the acceptance of which, with sympathetic coöperation on the part of the individuals, would do untold good.

The farmer, living isolated from his fellows, usually considers that he is sufficient unto himself. He obtains his drinking water from the most convenient source, which usually is a shallow well often located nearby his barnyard or privy, and thus open to dangerous contamination. The contents of his privy are never buried as a safeguard against disease, for his economical mind rebels against the waste of good fertilizing material. Hence it is spread upon his garden plot from which come the vegetables for his table, often to be eaten uncooked, and certainly always likely to be polluted. He considers not at all the fly menace, and aside from providing screens for his windows and doors, more for the exclusion of mosquitoes than flies, and which often keep more flies in than out, he regards the ubiquitous insect with tolerance, and calmly divides his food and drink with him without more than a petulant display of temper when a fly takes it into his head to fall into his milk, or become entangled in his butter or gravy. In some communities the consumption of corn on the ear takes on the aspect of an indoor sport, the human animal and the insect entering into friendly competion to ascertain who will get it first.

The ruralite is not particularly concerned if his sink, privy or barnyard drainage discharges into a brook from which his lower down neighbor takes his water supply. In fact, it is considered good rural engineering to lead such drainage direct to the nearest waterway. It would take a person of high intelligence and elo-

quence to teach convincingly the truth or logic of riparian rights to the average farmer, who is so prone to believe that it is wise to "Be not the first by whom the new is tried."

The greater prevalence of typhoid fever in rural districts, therefore, is due, primarily, to ignorance. If the people of one generation could be taught to believe that the house fly is a menace to health, and an especially active agent in the transmission of typhoid infected material; that a well located so that it can receive the drainage from the sink, privy and barnyard is a constant element of danger; that milk is a very favorable medium for the growth of the typhoid germ, and therefore should be collected with the greatest care and never handled by persons who are sickly, who come in contact with sick people, or who have had typhoid at one time or another; that garden truck should never be fertilized with human excrement; then each rural inhabitant would become a barrier in himself to the spread of typhoid fever, and benefit not only himself and his family, but the public at large. As it is, when persons so benighted become public purveyors of green vegetables and dairy products, a promising factor is introduced in favor of the propagation of typhoid fever. The high typhoid fever death rate in rural districts is due chiefly to the direct "from me to you" method of infection, and whether through the agency of bad water, flies or dirty hands, the typhoid germ has a much shorter and less difficult road to travel in the country than it has in the city.

HEALTH DEPARTMENT INADEQUACY

When heading this section the author was tempted to substitute inefficiency for inadequacy, because of the self-evident fact that most health departments, municipal and state, *do not* possess the power to act effectually. But inadequacy seems to fit the case less offensively as indicating that such boards as a whole, but largely through no fault of theirs, are not equal to the requirements.

It is nevertheless true that some health departments are neither headed nor manned by persons well qualified by knowledge, experience and energy to perform the highly responsible duties required of them. Unless a young man possesses independent means, or is of a philanthropic turn of mind, the salaries offered in health department work are such as promptly to discourage him in any fond dream of speedily acquiring the competence of a millionaire; but with the prevailing appropriations it cannot be otherwise.

It is a fact, perhaps not realized except by a few, that no thoroughly competent municipal or state department head fills that position except at a personal financial sacrifice. Where an official possesses the knowledge and experience competently to fill the position as chief of such a department, the salary offered is but a comparatively small measure of the financial return the same ability would command in private practice. Lack of satisfactory financial lubrication does not tend to make the machinery of the department run more smoothly or painstakingly, and the results accomplished by a year's hard work are so far removed from the spectacular, and therefore incapable of popular exploitation and comprehension, that they more often than otherwise go down to history "unhonored and unsung."

Occasionally, however, such epoch marking accomplishments as those of Jenner, Pasteur, Koch, Reed and more recently that of Gorgas in Panama, thrust before the reluctant-to-believe public mind the realization that a great step has been taken in conserving the health of mankind. But the road of the health official is usually a dreary one, unlightened even by an occasional fringe of primroses in the way of public commendation, and is made so by reason of the fact that it is his chief duty to prevent disease, and the measures of prevention are commonly distasteful to the public in whose interests he is acting. A successful year's campaign against filth in a city of 100,000 persons, resulting in the saving of a hundred lives, is publicly rewarded by a brief newspaper paragraph to the effect that the death rate has been reduced from 15 to 14 per thousand population, and is as promptly forgotten, if read at all. Few laymen realize that in thirty-three large world cities the annual general death rate has been lowered 37 per cent in the past thirty years. New York City's annual death rate has been nearly cut in half in that period. All this is lasting proof of the effects of better living, better understanding on the part of the public, better medical treatment of sickness and the wider exercise of measures of prevention. This last refers very prominently to purer water supplies, which item in itself, in the last thirty years, has been the means of a material reduction in the typhoid fever death rate in the United States as a whole, and in the cities which have adopted filtration the water borne typhoid has been practically stamped out.

The ways of public health work are sometimes devious, and often obscure. They cannot readily be understood by the layman. Therefore such financial support as health departments receive from the

public comes more or less grudgingly, even though the results obtained far outbalance the cost. Most of the diseases well understood by scientists are caused by a specific germ, and millions of such germs may be placed on the head of an ordinary pin, yet the havoc they can wreak, tiny as they are individually, is measurable only by comparison of their size with the pyramids of Gizeh. The lay mind can comprehend a visible menace against his life, like a moving vehicle or a club in the hands of an enemy, and will take steps to avoid it, but an enemy which must be magnified a thousand diameters that he may see it is beyond his understanding, and this is the enemy to mankind around which this paper is written.

HEALTH DEPARTMENT APPROPRIATIONS

For some reason, which patently has no good financial foundation, the amount of health department appropriations generally varies as the size of the city, that is, the larger the city the higher the per capita appropriation, as shown in the accompanying table. The budget adjusters evidently conclude that the smaller the city the less need there is for disease prevention.

These gentlemen, if examined on the point, might say, if they knew anything about it, that Augusta, Georgia, with an annual per capita health department appropriation of \$0.61, is quite as well off as Memphis, Tennessee, with one of \$0.93, since the general death rate is about the same in both cities, being a little lower, in fact, in Augusta. Aurora, Illinois, and South Bend, Indiana, appropriate \$0.03 per capita for health department work, yet their annual death rate from all causes is 6 per cent lower than in New York City, where the health department appropriation amounts to \$0.58 per capita. Easton, Pennsylvania, appropriates \$0.02 per capita as compared with \$0.61 in Pittsburgh, but the total death rate in both cities is about the same. On the other hand Seattle, Washington, where the health department appropriations are more liberal than in any other city in this country, amounting to \$0.98 per capita, has a death rate only 43 per cent as great as Lewiston, Maine, which is one of the stingiest cities in this respect, the appropriation there being but \$0.06 per capita per annum.

TABLE 2

General death rates in large world cities based upon total deaths from all causes

CITY	GENERAL DEATH RATES PER 1000 POPULATION LIVING														PER CENT DECREASE
	Averages						1909	1910	1911	1912	Averages				
	1881 to 1885	1886 to 1890	1891 to 1895	1896 to 1900	1901 to 1905	1906 to 1910					1881 to 1890	1891 to 1900	1901 to 1910	1911 to 1912	1881–1885 to 1910–1912
Amsterdam	25.1	22.4	19.2	16.7	14.7	13.1	13.1	12.2	12.4	11.2	23.7	17.9	13.9	11.8	53.0
Belfast	24.7	24.4	25.1	23.4	20.8	19.6	18.2	18.6	17.2	18.1	24.5	24.2	20.2	12.6	49.0
Berlin	26.5	22.4	20.5	18.1	17.0	15.5	15.1	14.7	15.6	14.4	24.4	19.3	16.2	15.0	45.0
Breslau	31.3	28.8	27.4	25.0	23.7	21.2	20.3	19.1	19.5	18.4	30.5	26.2	22.4	18.9	39.0
Brussels	23.4	21.2	20.2	17.2	15.2	14.1	13.9	13.6	13.9	13.5	21.8	18.7	14.6	13.7	41.0
Budapest	31.5	30.8	25.5	21.6	19.8	19.5	19.2	19.3	19.4	18.5	31.1	23.5	19.6	18.9	40.0
Christiania	19.9	22.3	19.0	17.5	15.3	13.0	12.7	11.9	13.5	13.4	21.1	18.2	14.1	13.4	32.0
Copenhagen	22.3	22.3	20.2	17.6	16.1	15.1	14.5	14.2	14.8	14.1	22.3	18.9	15.6	14.5	35.0
Dresden	25.0	22.1	20.6	19.0	17.6	14.7	14.0	13.8	14.6	13.1	23.5	19.8	16.1	13.8	44.0
Edinburgh	19.6	19.7	19.7	19.0	17.3	15.3	15.3	14.0	16.0	15.7	19.6	18.3	16.3	15.8	19.0
Glasgow	20.6	23.1	22.8	21.2	19.5	17.3	17.5	15.1	17.7	17.6	21.8	22.0	18.4	17.6	14.0
Hamburg	25.2	25.3	24.2	17.3	16.3	14.8	14.6	14.2	14.7	13.6	25.2	25.7	15.5	14.1	44.0
London	20.9	19.7	19.8	18.5	16.1	14.0	14.0	12.7	15.0	13.6	20.3	19.1	15.0	14.3	31.0
Melbourne	20.1	21.0	16.7	15.5	14.0	13.1	12.5	12.7	12.8	14.0	20.5	18.1	13.5	13.4	33.0
Milan	30.3	30.4	27.4	23.2	22.1	19.3	20.3	17.1	20.1	15.8	30.3	25.3	20.7	17.9	40.0
Moscow	33.3	33.6	29.2	28.7	26.6	27.6	29.6	26.9	27.2	24.3	33.4	28.9	22.1	25.7	22.0
Munich	30.4	28.3	25.8	23.9	21.0	17.4	17.6	15.9	15.8	14.7	29.8	24.8	19.2	15.2	50.0
Paris	24.4	23.0	21.2	19.2	18.0	17.5	17.4	16.7	17.2	16.3	23.7	20.2	17.2	16.7	33.0
Petrograd	32.8	26.8	25.3	24.6	23.5	25.5	24.6	24.1	20.8	21.9	29.8	24.9	24.5	21.3	35.0
Prague	32.7	29.6	27.1	24.3	22.6	19.3	19.1	18.4	16.3	15.8	31.1	25.7	20.9	16.0	51.0

Rio Janeiro	30.5	33.1	38.2	29.2	27.9	23.1	19.5	20.6	20.4	21.3	31.8	33.7	25.5	20.8	31.0
Rotterdam	24.2	22.0	20.8	18.0	15.6	13.4	12.6	12.2	12.1	11.3	23.1	19.4	14.5	11.7	51.0
Sydney	20.8	17.9	14.3	12.1	11.5	10.5	10.3	10.4	10.9	11.4	19.3	13.2	11.0	11.1	46.0
Stockholm	24.3	21.2	20.0	18.2	16.1	14.5	14.3	14.6	12.7	14.2	22.7	19.1	15.3	13.4	44.0
The Hague	23.3	20.8	18.7	16.2	14.4	13.2	12.7	12.5	12.7	10.9	22.0	17.9	13.8	11.8	49.0
Trieste	31.1	30.4	29.8	27.5	26.3	24.5	24.6	22.9	24.0	21.1	30.7	23.6	25.4	22.5	28.0
Turin	27.2	23.5	21.6	19.8	19.6	17.5	15.4	14.9	14.2	12.9	20.3	20.7	18.5	13.5	50.0
Venice	28.3	28.0	25.1	22.8	22.2	22.2	22.1	19.0	22.8	20.9	23.1	23.9	22.2	21.8	23.0
Vienna	28.2	25.1	24.1	21.1	19.1	17.0	16.8	15.8	16.4	15.4	26.6	22.6	18.0	15.9	43.0
Boston	24.9	23.5	23.6	20.9	18.8	17.9	17.7	17.2	17.1	16.4	24.2	22.2	18.3	16.7	32.0
Chicago	21.5	19.5	20.6	15.2	14.2	14.5	14.1	15.1	14.5	14.8	20.5	17.9	14.3	14.6	32.0
New York	27.5	25.8	24.6	20.3	18.9	17.0	16.2	16.0	15.2	14.5	26.6	22.4	17.3	14.8	47.0
Philadelphia	22.3	20.6	21.1	19.2	18.1	17.7	15.9	16.8	16.6	15.3	21.9	20.1	17.9	15.9	28.0
Averages	25.9	24.5	22.7	20.4	18.8	17.3	16.8	16.2	16.5	15.7	24.8	21.1	17.8	15.9	37.0

*Health Department appropriations of cities by size groups**

POPULATION	CITIES REPORTING	AGGREGATE POPULATION	AVERAGE POPULATION	ANNUAL APPROPRIATION PER CAPITA
				cents
300,000 and over	17	16,087,038	946,296	40.3
100,000 to 300,000	38	6,045,943	159,104	27.9
50,000 to 100,000	55	3,890,259	70,732	20.3
25,000 to 50,000	96	3,465,081	36,095	19.8
All cities.................	206	29,488,321	143,147	32.7

* Compiled from "A survey of the activities of municipal health departments in the United States" by Franz Schneider, Jr., of the Russell Sage Foundation. *American Journal of Public Health*, January, 1916.

These very things make it difficult for the heads of health departments to obtain appropriations of sufficient size. Practically their only statistical argument may be based on the records in their own cities for several years back. If street cleaning, garbage collection, disposal of dead animals and night soil are not done with dispatch the citizens are sure to raise an outcry, and if these duties happen to come within the scope of the health department the director has a chance to air his grief over small appropriations. But with respect to the work of the important division of preventive medicine in the health department, under which may be listed efforts looking to the conservation of the purity of food and drink, tuberculosis work, tenement house and factory inspection, laboratory and dispensary service, and inspection of school children, the results are not capable of noisy exploitation; indeed it is sometimes difficult to show improvement, for it requires years of hard work, with never a lessening of energy, to effect lasting good, and consequently the attendant difficulty in obtaining money to carry on the work is apparent.

It cannot be denied, in the face of indisputable statistical facts, that public health service has raised the health tone of the world in a very material measure, and at this point it may be well to present certain statistics in support of this assertion.

The data contained in Table 2 show that some force, or set of forces combined, was responsible for the marked decrease in the death rate in these thirty-three large world cities, having a combined population of 40,000,000. As compared with thirty years ago the

average general death rate in these cities has decreased 37 per cent, which is actually to say that of each 100,000 population 1000 less people die each year than formerly. Based upon present day populations this means that if the old health conditions had obtained in 1912 in these cities totalling 40,000,000 people, a total of 1,036,000 would have died annually, instead of 628,000, as was actually the case. One in sixty-three died in the year 1912 as against one in thirty-nine thirty years previously.

HEALTH REGULATIONS AND THEIR ENFORCEMENT

In some states there is a wide array of public health laws, some obtuse in their wording, some apparently impossible of execution, but in the best cases the subject is well covered on the whole, and the laws fully ample if they could but be enforced. In other states there is little or no health law or order, and particularly is this noticeable in the southern states.

The government receives and compiles mortality statistics from certain states in the Union, termed "Registration States." The distinction between a registration and a non-registration state is that in the latter vital statistics either are not kept at all, or are so incomplete or inaccurate as to fall under the ban of the Government statisticians. At the close of 1913 the following classification obtained:

Registration states. Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, North Carolina, Ohio, Kentucky, Indiana, Michigan, Wisconsin, Minnesota, Missouri, Montana, Colorado, Utah, California, Washington and the District of Columbia.

Non-Registration states. West Virginia, South Carolina, Georgia, Florida, Tennessee, Alabama, Mississippi, Illinois, Iowa, Arkansas, Louisiana, North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, Texas, New Mexico, Arizona, Wyoming, Idaho, Nevada and Oregon.

Included in the above list of non-registration states are the populous states of Alabama, Arkansas, Georgia, Illinois, Iowa, Kansas, Louisiana, Mississippi, Nebraska, Oklahoma, South Carolina, Tennessee and West Virginia, which, in themselves, constitute 30 per cent of the total population of the United States. To draw

a stricter line of distinction, however, let it be stated that in all the non-registration states in 1913 there were forty-one registration cities with a total population of about 5,200,000. This left a total of about 25,000,000, or about 26 per cent of the total population of the country, where the records of death are so poorly kept, if kept at all, that they were considered unworthy of recognition by the United States government.

Vital statistics serve as a barometer by which the health of the nation may be determined. In this great country one quarter of the people are without such information. If the healthfulness of a people governs the productive power thereof, as it surely does, the lack of reliable statistics from these twenty-five millions of people is mighty poor state and municipal bookkeeping. People are always very particular in demanding a record of real money expenditures, but the ever prevailing list of preventable deaths is one of the greatest leaks in the reservoir of productiveness, and among a quarter of the people of this country no reliable measurement of this leak is made.

TABLE 3

Growth of the area of registration for deaths

YEAR	TOTAL POPULATION UNITED STATES*	REGISTRATION AREA			
		Population		Land Area	
		Number	Per cent of total	Square miles	Per cent of total
1880	50,156,000	8,538,000	17.0	16,480	0.6
1890	62,622,000	19,659,000	31.4	90,700	3.0
1900	75,995,000	29,800,000	39.2	194,200	6.5
1905	84,219,000	34,052,000	40.4	212,700	7.2
1906	85,837,000	41,983,000	48.9	603,100	20.3
1907	87,455,000	43,017,000	49.2	603,200	20.3
1908	89,073,000	46,790,000	52.5	725,100	24.4
1909	90,691,000	50,871,000	56.1	765,700	25.7
1910	92,309,000	53,844,000	58.3	998,000	33.6
1911	93,927,000	59,276,000	63.1	1,106,700	37.2
1912	95,545,000	60,427,000	63.2	1,106,800	37.2
1913	97,163,000	63,299,000	65.1	1,147,000	38.6

* Land area 2,974,000 square miles.

A community may start out with the best intentions. Legislative enactments are put through to protect the public health.

This is simple, for none but the framers of health laws really know what they signify, hence there arises no antagonism to their enactment. Next comes the task of obtaining the necessary funds to enforce these laws. The average appropriation of all the cities where such funds are made avaliable is in round numbers 30 cents per capita per annum. This applies only to those cities having populations of 25,000 or more. What of the remainder?

Let any thinking citizen ask himself if he considers a contribution of 30 cents each year on his part sufficient justification for his assurance of protection against preventable disease. Or, as another example, if he thinks, if given in charity, it is his proper share toward the fund for keeping in check and preventing the spread of the great white plague, which kills 130,000 people in America each year. Unquestioningly he would give far more to street beggars in the course of a year. If every man, woman and child in the United States contributed one dollar each year to public health work, the total sum thus raised would not nearly equal the annual loss in vital capital in this country from typhoid fever alone. Not one city in America does contribute one dollar per capita for all the uses of its health department, but on an average contributes the farfamed thirty cents, which is opprobrium enough.

In the states best off with respect to health laws recorded on their statute books, the proper enforcement of these laws is never carried out. Observe the anti-spitting law enacted only a few years ago. No law was more proper, but in the beginning, when an arrest for its violation was made, it was so unusual a proceeding that the ensuing brief court proceedings were likely to find their way to the front page of the newspapers, and for days thereafter the cartoonists were busy with their humorous pencils creating and nursing a spirit of mockery so often fatal to the public good. The law prevailed, nevertheless, more through the effects of ingenious placarding of the statute than a fear of legal apprehension, or an honest belief that disease was spread in this manner.

Laws looking to the prevention of contamination of food and drink commonly are allowed to lie peacefully within the covers of the books of law, seldom to be disturbed. The screening law, calling for the protection of foods exposed for sale from the explorative activities of the deadly house fly, was observed where there was no apparent way out of it, but the screens, when provided, were often improperly constructed, and since they were more or less of a nuis-

ance to the owner in disbursing his wares, were never more than partly effective.

In fact, as with the majority of all health laws, the collective public affected thereby observes them with reluctance, protestingly, and without sincerity. If all the good health laws, laws which actually should be observed, were rigidly enforced, there would not be enough jail room in any city to accommodate the violators thereof, nor court officials enough to try the cases.

All public health laws have a penalty attached for violation. commonly it takes the form of a ridiculous fine or term of imprisonment. The arms of the law hesitate to make arrests, and the court usually limits the penalty to a reprimand, not infrequently administered to the officer making the arrest. Both fear an outburst of indignation accompanied by claims of discrimination and persecution, the officer from the court, and the court from the public, since the general violation of such laws by the public is so common.

It may be an oldfashioned idea, but it would be supposed that laws are framed and enacted for some good purpose, and that they are expected to be enforced, but if even such laws as now stand on the statute books were rigidly enforced the introduction of a sea of amendments would immediately follow, and in the meantime many new faces would appear in the health, police and judiciary departments. The American public, in this day and generation, will not tamely submit to being forced to do without anything in the form of a privilege to which it has become accustomed.

A community blessed with reasoning power impelling sensible appropriations for public health work, adequate laws and officials courageous enough to enforce them, has progressed far in the direction of Utopianism. Cleanliness is indeed next to godliness, but so imperfectly is its meaning understood that a fair bulk of the country's population think it means merely a good cleanup on Saturday night, and keeping one's thumb out of the other fellow's soup.

CAMPAIGNS FOR PURE WATER SUPPLIES

No one can gainsay that in progressive states the majority of the movements looking to the improvement of public water supplies originate in the health department. Especially is this true where the community is small, and where the water department officials do not feel warranted in employing relatively expensive men who

are technically trained in water analysis and matters in general relating to water pollution. Then, too, the officials of large cities often are slow to act in such matters, and too prone to fall back upon arguments based on the financial inability of the community to carry through the construction of water purification works. It can be stated unqualifiedly that no community, whatever its size, is too poor to have a pure water supply. It is better to have bad streets, grade crossings, and inadequate public buildings, than to tolerate a public water supply of questionable purity.

Grade crossings are a menace to life, to be sure, but not nearly as great a menace as a bad water supply; and they are more often abolished for the sake of convenience than as a measure of public safety. Good streets promote business and the public comfort, but such improvements do not measure up on a level of importance with a supply of pure water. Attractive, roomy and light public buildings are a matter of common civic pride, but it is doubtful if they tend materially to increase the efficiency of those who labor therein.

Of all public works the water works is by far the most important, and should always be given preference in the allotment of moneys for the city's maintenance. Ever since it became known that bad water was dangerous to health the public has been entitled by sovereign right to receive pure water. Bad water will put out conflagrations as promptly as pure water, but it also will cause widespread disease, which is more important. In the last thirty-odd years the loss in vital capital through typhoid fever alone was over three times the net property loss from fire in the United States.

It is the customary design that the water works department of a community shall be self supporting, but it is rare that large sums of money are kept on hand to defray extraordinary expenses in the department. When questions arise as to the adequateness of the supply as regards volume, or more satisfactory distribution, little difficulty is experienced in obtaining the necessary funds to carry out the work, for the comfort and convenience of the public are affected. With improvements in the supply respecting purification it is different. When a city of a hundred thousand people is confronted with evidence furnished by its own officials and those of the state health department showing that the water supply requires purification, and learns that works to effect this end will cost, say, $300,000, there follows an energetic sharpening of pencils

to ascertain how this is going to affect the tax rate. There is strong opposition to the movement from the very beginning.

The state health officials, realizing the necessity better than anyone else, order that purification works be built. The cost thereof being estimated, the matter of a bond issue to carry the expense is put up to the people, and very often is defeated. Then an extension of time is allowed, and the matter drifts along for years without any definite advance.

Many cities have endured an excessively high typhoid fever death rate for years, and withheld the financial support necessary for the furtherance of measures of prevention, even when it was plain that the public health of the community would be immensely benefited thereby. Great cities, such as Baltimore, Cincinnati, Louisville, Minneapolis, Philadelphia, Pittsburgh, St. Louis and Washington, temporized with the matter for years before building purification works, and in the meantime thousands of their citizens were needlessly killed by waterborne diseases. Then they built filter plants, and it is safe to say that if a candidate for public office in any of these cities should advocate the abandonment of filtration, he would stand as much chance of election as the proverbial snowball has of existence in Gehenna. The people in these cities now realize what pure water means to them, and while at first reluctant to believe, actual experience of the benefits has turned their minds just as far, or farther, in the opposite direction.

Laws have been enacted giving to the state the power to force the purification of public water supplies within their boundaries. The socalled Bense Act of Ohio is one of these. There is need of more legislation of this kind, which leads to the protection of the public against itself. Such power, placed in competent hands, and with sufficient funds to enforce it, cannot but do immeasurable good. Too much reliance is put in moral suasion in such matters nowadays. The money can always be found if it has to be found, and many a man has put off the urgently necessary visit to the dentist because of the physical pain incident to such a visit, and the strain on his pocketbook; but he is always happy and satisfied when it is all over.

It is precisely so with forced expenditures of public money for water purification. The thinking citizen realizes that he is taking a chance with disease every time he drinks a glass of contaminated city water, and yet is ready with excuses, chiefly of a financial nature, for not helping along the campaign for pure water; but no matter

what he finally is compelled to pay for it, when he realizes how he has been benefited he is perfectly satisfied, even though for a time he is obliged to go without new paving in front of his house, apologize to visitors for his antiquated city hall, or something of the sort.

STATE BOARD OF HEALTH APPROVAL OF WATER IMPROVEMENT PROJECTS

It is probable that about twenty-five years ago the health departments in different states began to realize the importance of some sort of control over the water supplies of communities located within their borders. Twenty years ago the legislative acts, under which some of these boards operated, required that plans for new water works installations be filed with them. At that time, however, they had little or no authority to take action on such plans. The powers vested in them since then, however, have been increased, until at the present time, practically without notable exception, all state health departments may, at discretion, reject plans for new installations or improvements in water works in general, including water purification works. It is very questionable whether the efficiency of the health departments, as to the specific qualifications of its officials, has kept pace with the increased power given them.

When a city has decided to install a water purification plant, plans and specifications thereof formally are presented to the state health department, for under the law in many states such plans and specifications must be approved by that department before construction work can proceed. This should be a most desirable procedure, for it guards against the construction of plants unsuited to the local conditions, and it should lend to a community a feeling of confident security.

Where the health officials, who thus hold an arbitrary position, are qualified by experience and ability to pass on such matters, and where they are fair minded into the bargain, the plan works out to the advantage of all. If they are not competent, however, their actions retard progress, and may be such as to prevent the installation of an entirely suitable, well designed, adequate work, or permit the installation of a plant which is entirely unsuitable, actually dangerous, and a menace to the health of the community.

Some states are blessed with the good fortune of having health departments the personnel of which is of high standard, and consequently the results accomplished are worthy of far greater public

recognition than they usually receive. Other states are less fortunate. These also should receive the careful consideration of the public, to the end that they be brought up to a standard of real usefulness.

The author believes that an important and controlling amendment to all existing public health laws should be made, particularly those surrounding the contemplated purification of public water supplies. To promote the health and comfort of such a community the law should require that the water as delivered to the consumer comply at all times with reasonable standards of purity, essentially as regards its bacterial content and physical characteristics. Furthermore, that any method of purification, tangibly guaranteed continuously to furnish a water at all times complying with the law, shall be acceptable. The physical features of such purification plants thus would not be subject to approval by the health department, it being the duty of that department, as is eminently proper, to see to it that the guarantees under which the plant was constructed are fully complied with.

Most public health laws governing water purification projects specify that plans and specifications of the contemplated works shall be submitted to the health department, and that construction work shall not be begun until the health department has indicated its approval thereof. No time limit is set for such action by the health department, and this is needed to preclude unnecessary inaction, provided the law delegating to the health department the power to approve or reject a project on the plans and specifications is allowed to stand. As these laws now read the approval of such projects may, for one reason or another, be delayed indefinitely and to enforce action mandamus proceedings provide the only way out of the difficulty. There are cases on record where water purification projects have been held up for many months, and even killed, by the prejudicial attitude of the health department toward the rapid sand process of filtration. The improper use of power in this manner is clearly against the interests of the state, and its further exercise should be prevented by legislative action.

TYPHOID FEVER IN THE UNITED STATES

In the following tables there is given a fairly complete survey of the death toll from typhoid fever in the United States. Exceptional

accuracy is not claimed for these statistics, for the reason that the data were of necessity compiled from United States Census, state and municipal reports, which in many cases agree only approximately. In some places mortality statistics have been kept but a relatively short time, and frequently there is marked conflict between local reports and the summaries of the United States government. In the appendix a number of tables of detailed data will be found.

TOTAL AND TYPHOID FEVER DEATH RATES IN THE REGISTRATION STATES

In Table 4 and Plate 1 a comparison is made of the deaths from all causes and from typhoid fever, respectively, in the registration states for the years 1910–1913, inclusive. The data have been arranged so as to show the relative mortality in urban and rural districts.

The mortality census of something over one half of the total population of the United States is thus presented. In brief the data show

TABLE 4

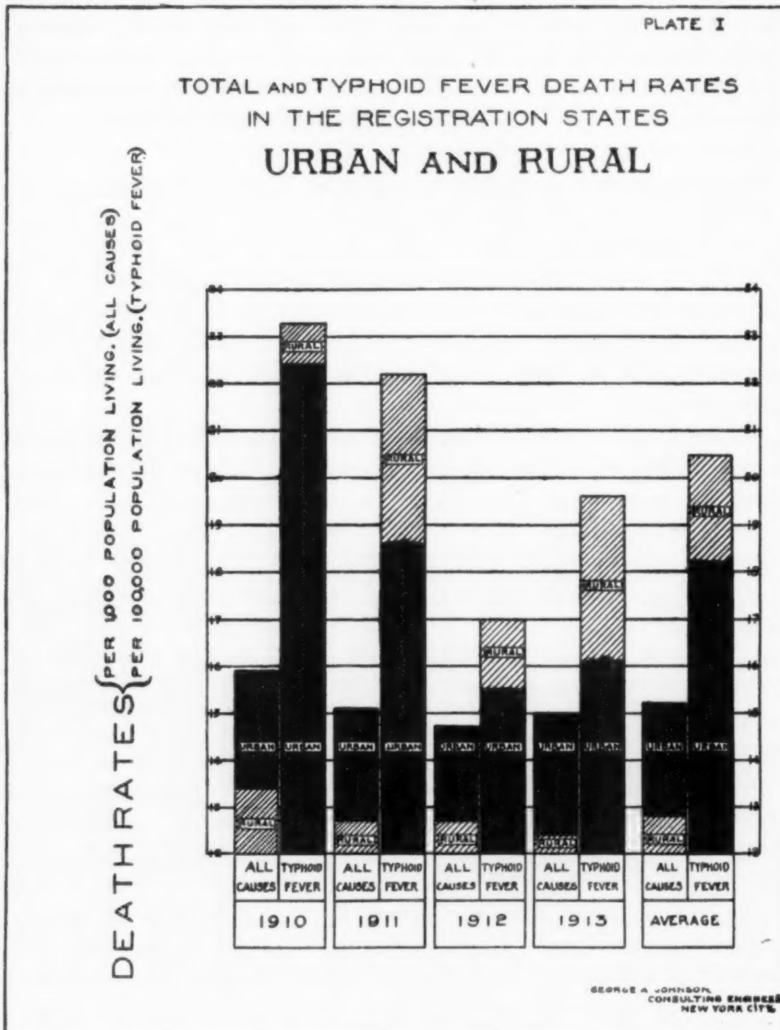
Total and typhoid fever death rates in the registration states. Urban and rural

YEAR		1910	1911	1912	1913	AVERAGE
Population	Urban......	25,047,000	27,303,000	28,130,000	29,244,000	27,431,000
	Rural.......	22,563,000	25,942,000	27,122,000	29,069,000	26,174,000
	Total.......	47,610,000	53,245,000	55,252,000	58,313,000	53,605,000
	Per cent, registration states of total United States....	51.5	56.7	57.8	60.0	56.6
Rates, all causes*	Urban......	15.9	15.1	14.7	15.0	15.2
	Rural.......	13.4	12.7	12.7	12.4	12.8
	Total.......	14.7	13.9	13.6	13.9	14.0
Rates typhoid fever†	Urban......	22.4	18.6	15.5	16.1	18.2
	Rural.......	23.3	22.2	17.0	19.6	20.5
	Total.......	22.8	20.4	16.2	17.8	19.3

* Per 1000 population living.

† Per 100,000 population living.

a small but gradual decrease in the general death rate during the four years in question, that for 1913 being about 5.5 per cent lower



than the rate for 1910. The reduction in the typhoid fever death rate during the same period was more marked, the rate for 1913 being some 22 per cent lower than that for 1910.

The data also show that the death rate from all causes in the rural districts is consistently lower than that of urban districts, and is decreasing more rapidly; while, contrariwise, the typhoid fever death rate is lower in the urban districts and is decreasing more rapidly than in the rural districts.

This is in some respects a gratifying, but not unexpected showing. As regards the death rate from all causes, it was to be anticipated that city life would be shown to be generally less healthful than country life. As regards the preventable disease, typhoid fever, the results are just such as might be expected. Sanitation is bound to progress more slowly in the country where education is less of a helpful factor, where the treatment of the patient is often attempted at home with all the attending dangers of secondary infection, and last, but by no means least, where the domestic "sanitary" conveniences are neither convenient nor sanitary, and where the house fly is allowed free rein to exercise his malignant practices. In cities the sanitary conveniences in general are really sanitary, the fly is less of a domestic pet, and a majority of the large cities have pure water supplies. The hospitals are made more use of in the treatment of typhoid cases, and the all around care of the disease is on a much higher plane of efficiency.

Probably the best illustration of the relative prevalence of typhoid fever in urban and rural districts was presented a dozen years ago by Dr. John S. Fulton,[1] and a digest of his data is presented in Table 5. These statistics are of the most convincing character.

TABLE 5

Relative prevalence of typhoid fever in urban and rural districts

NUMBER OF STATES	PER CENT WHICH THE URBAN POPULATION WAS OF THE TOTAL POPULATION	AVERAGE PER CENT OF RURAL POPULATION	AVERAGE TYPHOID FEVER DEATH RATE PER 100,000 POPULATION
5	Over 60	30	25
6	40 to 60	49	42
7	30 to 40	67	38
8	20 to 30	75	46
12	10 to 20	87	62
12	0 to 10	95	67

[1] Annual Report of the State Board of Health of Maryland for 1903.

SEASONAL DISTRIBUTION OF TYPHOID FEVER

Typhoid fever is essentially a disease of the summer and autumn. In the broad analysis of the mortality statistics, whether from rural or urban districts, just so sure as June comes around it is equally certain that an increase in the typhoid fever death rate will occur, but this increase is far greater in the country than in the city.

In this connection it is to be borne in mind that the data herein discussed, for the most part, do not include statistics from southern countries where the winters are warmer. The sole reason why such statistics are not used is that there are no such figures available.

TABLE 6

Typhoid fever death rates in the registration states, seasonal distribution

MONTH	TYPHOID FEVER DEATH RATE PER 100,000 POPULATION LIVING				
	1910	1911	1912	1913	Average 1910–1913
January	15.7	16.8	15.1	10.8	14.6
February	14.5	15.4	12.0	9.6	12.9
March	16.3	14.6	13.0	9.7	13.4
April	14.3	13.2	11.5	9.0	12.0
May	12.1	12.5	11.4	11.0	11.8
June	13.1	14.7	10.8	12.1	12.7
July	16.7	17.5	14.4	19.7	17.1
August	30.8	30.7	20.8	27.8	27.5
September	41.8	30.7	25.0	29.1	31.6
October	42.5	33.4	25.9	29.2	32.8
November	34.3	27.4	19.1	21.0	25.5
December	23.0	18.5	16.1	15.8	18.4
Averages	22.9	20.8	16.2	17.1	19.2

Estimated total population { 1910, 47,610,000. 1911, 53,245,000. 1912, 55,252,000. 1913, 60,980,000.

Rural population of the registration states about 48 per cent of the total

These data show that every year, just previous to the advent of summer, the typhoid fever death rate is at its lowest mark. In June the beginning of the annual rise is first noted, and the rate increases from then on until the autumn, when the decrease begins, the rate reducing gradually through the winter months.

What forces are operative to bring about this persistent phenomenon? Why is typhoid more prevalent in the warm months of the year? Why does not the disease drop off abruptly with the advent of cold weather, instead of gradually, and only reaching its lowest ebb at the close of winter and the advent of spring?

There is nothing in an argument that the general health tone of the public at large is highest in the warm months of the year. The records from 60,000,000 people in this country show that during the six months, May to October, inclusive, 48.5 per cent of the annual deaths occur, as against 51.5 per cent for the six-month period, November to April, inclusive.

TABLE 7

Typhoid fever death rates in large American cities, seasonal distribution

MONTH	TYPHOID FEVER DEATH RATE PER 100,000 POPULATION LIVING				
	1910	1911	1912	1913	Average 1910–1913
January	15.0	11.4	13.2	7.5	11.8
February	14.8	9.4	8.3	7.7	10.0
March	16.4	10.0	7.1	7.5	10.5
April	12.8	8.4	8.8	7.2	9.3
May	11.7	9.7	7.3	9.8	9.9
June	12.4	11.0	9.4	9.8	10.4
July	13.9	15.1	11.8	13.4	13.5
August	22.5	22.1	17.8	17.4	19.9
September	29.3	22.0	17.2	19.2	21.9
October	25.2	18.2	15.3	22.1	20.2
November	22.6	18.7	10.5	16.4	17.5
December	16.6	13.6	10.0	11.9	13.0
Averages	17.7	14.1	11.4	12.1	13.9

Estimated total population $\begin{cases} \text{1910, 15,463,000.} \\ \text{1911, 15,968,000.} \\ \text{1912, 16,306,000.} \\ \text{1913, 16,708,000.} \end{cases}$

In the warm months the public feeds more largely on uncooked green fruits and vegetables, and considering impure foods as media for typhoid infection, green fruits and vegetables consumed uncooked unquestionably are the most liable to dangerous contamination through the agency of flies, and handling by persons whose fingers are soiled with typhoid infected excreta.

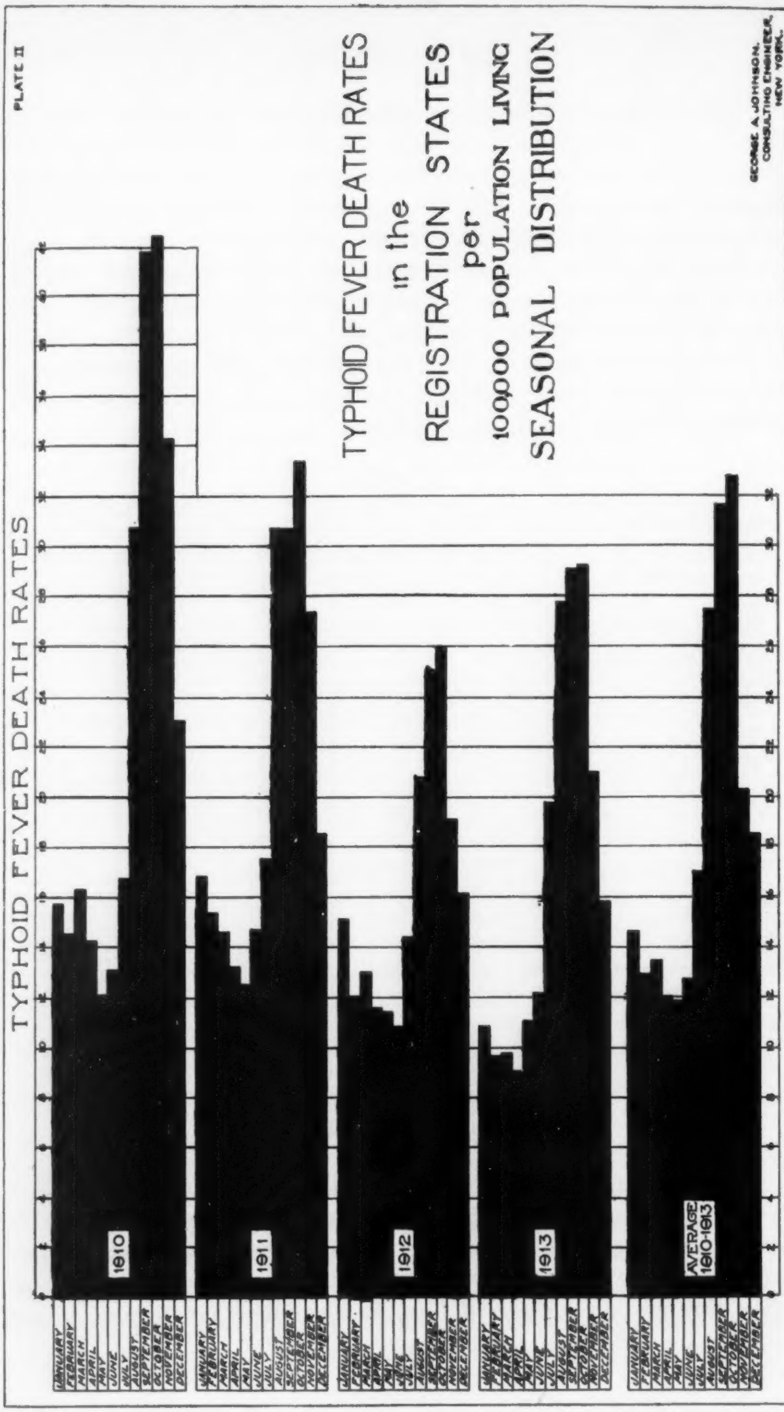


PLATE II
TYPHOID FEVER DEATH RATES
TYPHOID FEVER DEATH RATES
in the
REGISTRATION STATES
per
100,000 POPULATION LIVING
SEASONAL DISTRIBUTION
1910
1911
1912
1913
AVERAGE 1910-1913
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
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In the winter the watersheds of streams and lakes are often frozen up, and the streams draining them also are frequently frozen over, and for these two reasons public water supplies receive less polluting matter from the rural districts and semiurban districts where the selfemptying privy is still used. Alternate freezing and thawing also tends to kill the typhoid germ more quickly. With the advent of warmer weather thaws occur, and the winter accumulations of filth are washed from the catchment areas into the streams and lakes. Stream pollution is thus made doubly dangerous because of the sudden addition of the winter accumulations. Communities which do not purify their public water supplies thus suffer from an increase in typhoid fever with the advent of warm weather.

Throughout the summer the contributions of sewage from the watershed continue without cessation, being aggravated occasionally by heavy rains which flush off the catchment area and badly soil the rivers and lakes which drain it. The brooks and rivers are no longer frozen over even a part of the time. They promptly get all the filth the watershed can contribute. Without an efficient purification plant in the water works system, the communities using such surface waters must expect to pay, and do pay, a corresponding toll to typhoid fever in consequence of their neglect.

The house fly begins to get in its underfoot work as soon as the warm weather appears. It is midsummer, however, before he fully gets into his stride. All the time typhoid fever has been gradually increasing, and reaches its apex in the early autumn. The fly, also, begins to disappear about this time, and is observed to go about its self imposed duties of carrying typhoid germs to the table from the privy and elsewhere with greater reluctance and less dispatch.

With the advent of winter the typhoid rate begins to fall off, but not rapidly. Dry weather obtains and less polluting matter enters the streams. The activities of the house fly diminish rapidly. But the typhoid patients of the summer and autumn furnish the seed for the crop of winter typhoid through the important medium of secondary infection, and the typhoid death rate gradually falls off as the number of new cases decreases. And thus the annual cycle is completed, a new one to be begun the following summer.

SEASONAL DISTRIBUTION OF RURAL AND URBAN TYPHOID

Referring back to Tables 6 and 7 and Plate II, it is instructive to compare the seasonal distribution of typhoid fever in the registra-

tion states, which includes statistics for both the rural and urban population, and the same class of data for large cities. It is already understood, of course, that the rural typhoid death rate is higher than the urban, but a point of real significance is lost sight of until the following comparison is made, as shown in Table 8 and Plate III.

TABLE

Comparison of the combined rural and urban typhoid fever death rate with that in large cities (average for four years 1910–1913)

MONTH	TYPHOID FEVER DEATH RATE PER 100,000 POPULATION			EXCESS OF DEATH RATE IN STATES OVER CITIES
	Registration States	Registration Cities	Excess of States over Cities	
				per cent
January	14.6	11.8	2.8	24
February	12.9	10.0	2.9	29
March	13.4	10.5	2.9	28
April	12.0	9.3	2.7	29
May	11.8	9.9	1.9	19
June	12.7	10.4	2.3	22
July	17.1	13.5	3.6	27
August	27.5	19.9	7.6	38
September	31.6	21.9	9.7	44
October	32.8	20.2	12.6	62
November	25.5	17.5	8.0	46
December	18.4	13.0	5.4	42
Averages	19.2	13.8	5.4	39

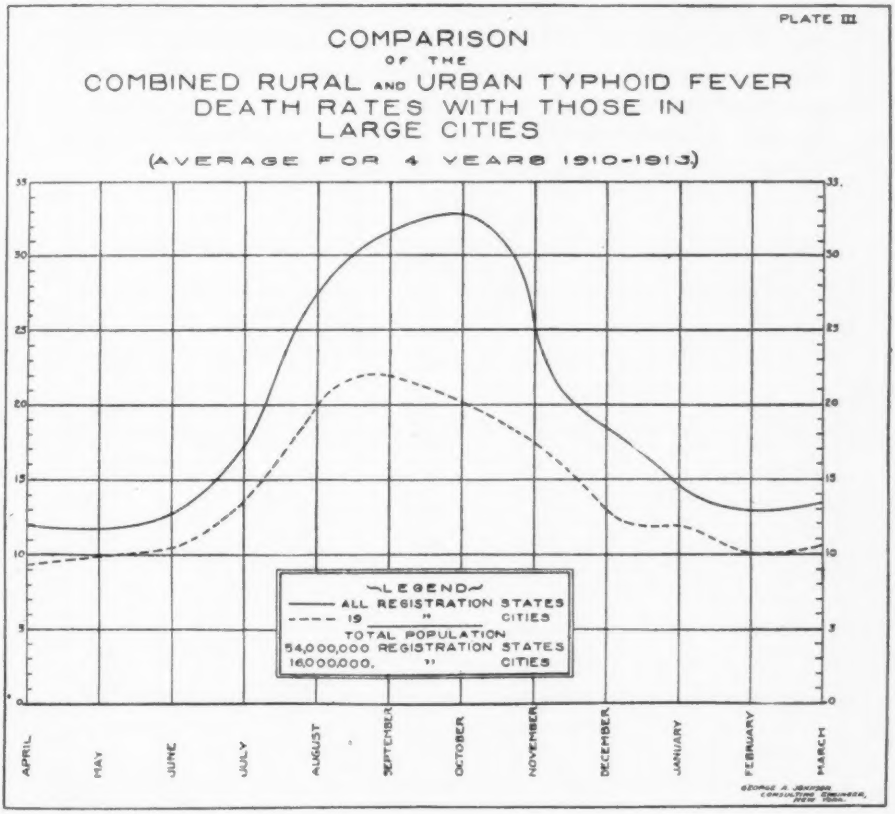
NOTE: Figures for the registration states cover a population of some 54,000,000. The figures for the large American cities were compiled from the statistics of nineteen of the largest American cities, having a total population of 16,000,000. (See Appendix Tables 26 to 30, inclusive.)

The foregoing data are pointedly significant. In the registration states, which include the rural as well as the urban population, the typhoid fever death rate is always higher than that for the cities, averaging 39 per cent higher, in fact, during a total period of four years.

Now the rural population of the registration states amounted to about 26,000,000 out of a total population of 54,000,000. Its effect on the much higher typhoid fever death rates in whole states

as compared with cities, is plain. It is instructive to compare these data with those given in Table 5.

The comparison is not so fair of course, as the one made in Table 4, nevertheless it serves to emphasize the point that rural districts are intensified cultures from which a continuous stream of typhoid is fed to the city dweller through the media of polluted water, milk and other dairy products, and green fruits and vegetables.



Observe in Table 8 how much lower is the typhoid increase in the cities as summer approaches, and waxes and wanes into autumn, than in the states as a whole. The endemic typhoid in the latter is always greater than in the cities, and when the warm weather comes typhoid fever holds high carnival in the country. It has fewer agencies to combat it than in the city, and when the peak of

the annual typhoid curve is reached in October, the city typhoid fever death rate is less than two-thirds of that of the combined rural and urban population.

DEATH RATES FROM DISEASES OF THE RESPIRATORY ORGANS

While it may seem somewhat out of place in this paper to discuss specific diseases other than typhoid fever, several facts confronted the author as the statistical data came together which seemed to require explanation. As already pointed out, the general death rate from all causes is more or less of a constant throughout all seasons of the year, while typhoid fever is decidedly a warm weather disease. Likewise, diseases of the respiratory organs are more fatal during the cold months, as would be expected.

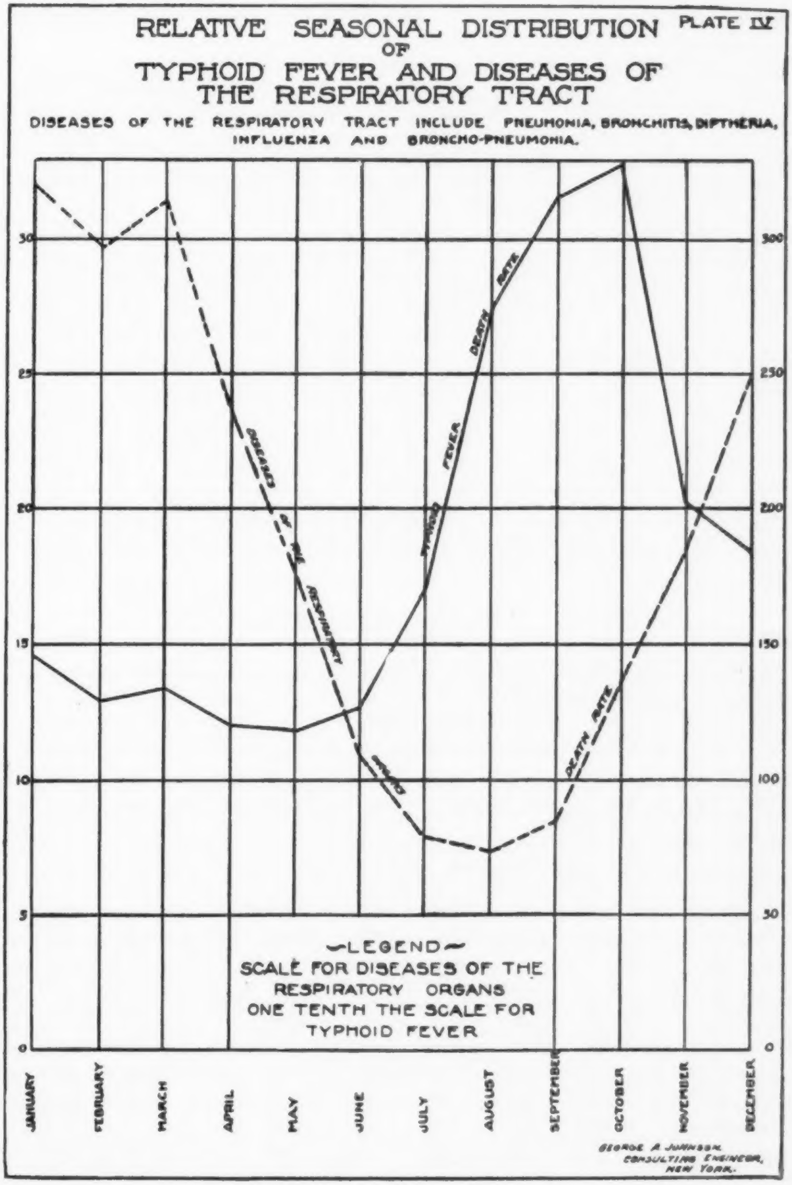
TABLE 9

Death rates of the diseases of the respiratory organs in the registration area, seasonal distribution

MONTH	DEATH RATES PER 100,000 POPULATION LIVING				
	1910	1911	1912	1913	Average 1910–1913
January	313	356	291	324	321
February	289	316	282	303	297
March	341	324	287	310	315
April	260	257	218	211	236
May	206	176	158	162	175
June	132	87	100	115	109
July	90	75	72	77	79
August	82	72	73	71	74
September	98	83	83	77	85
October	145	130	142	122	135
November	216	184	172	166	184
December	304	223	272	205	251
Averages	207	188	180	181	189

Estimated total population in the registration area (Including registration cities in non-registration States) 1910, 53,843,900; 1911, 59,276,000; 1912, 60,427,200; 1913, 63,298,700

In Table 9 and Plate IV this point is plainly brought out, and it is interesting to note from the diagram the balancing effect of the winter mortality from diseases of the respiratory organs on the warm weather mortality from typhoid fever.


RELATIVE SEASONAL DISTRIBUTION
OF
TYPHOID FEVER AND DISEASES OF
THE RESPIRATORY TRACT
PLATE IV
DISEASES OF THE RESPIRATORY TRACT INCLUDE PNEUMONIA, BRONCHITIS, DIPTHERIA,
INFLUENZA AND BRONCHO-PNEUMONIA.
0
5
10
15
20
25
30
0
50
100
150
200
250
300
DISEASES OF THE RESPIRATORY ORGANS
TYPHOID FEVER DEATH RATE
DEATH RATE
LEGEND
SCALE FOR DISEASES OF THE
RESPIRATORY ORGANS
ONE TENTH THE SCALE FOR
TYPHOID FEVER
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
GEORGE A. JOHNSON,
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NEW YORK.

TABLE 10

Total deaths from all causes in the registration area and per cent distribution by age

AGE	TOTAL DEATHS AVERAGE FOR FOUR YEARS	PER CENT DISTRIBUTION				
		1910	1911	1912	1913	Average for 4 years
years						
Under 5	214,142	27.0	25.0	24.4	25.3	25.4
5 to 9	18,386	2.2	2.2	2.6	2.2	2.4
10 to 19	32,836	3.9	3.9	3.8	3.9	3.8
20 to 29	65,618	7.8	7.9	7.3	7.8	7.7
30 to 39	72,634	8.5	8.8	8.5	8.4	8.5
40 to 49	77,397	9.1	9.2	9.2	9.1	9.2
50 to 59	89,171	10.1	10.5	10.9	10.8	10.5
60 to 69	104,400	12.0	12.3	12.7	12.4	12.4
70 to 79	104,187	11.9	12.4	12.7	12.4	12.4
80 and over	65,277	7.5	7.8	7.9	7.9	7.7
Totals..................	818,448	100.0	100.0	100.0	100.0	100.0

TABLE 11

Total typhoid fever deaths in the registration area and per cent distribution by age

AGE	TOTAL TYPHOID DEATHS					PER CENT DISTRIBUTION				
	1910	1911	1912	1913	Average for four years	1910	1911	1912	1913	Average for four years
years										
Under 5	629	675	536	627	617	5.0	5.4	5.4	5.5	5.3
5 to 9	684	747	643	759	708	5.4	6.0	6.4	6.7	6.1
10 to 19	2,534	2,551	2,017	2,369	2,368	20.0	20.4	20.2	20.9	20.4
20 to 29	3,780	3,502	2,815	3,183	3,320	29.8	28.1	28.2	28.2	28.6
30 to 39	2,186	2,148	1,677	1,741	1,938	17.3	17.3	16.8	15.4	16.7
40 to 49	1,341	1,245	1,036	1,230	1,213	10.6	10.0	10.4	10.8	10.4
50 to 59	869	829	662	754	778	6.9	6.8	6.6	6.6	6.7
60 to 69	405	486	391	429	428	3.2	3.9	3.9	3.8	3.7
70 to 79	192	203	167	165	182	1.5	1.6	1.7	1.5	1.6
80 and over	53	65	43	66	57	0.3	0.5	0.4	0.6	0.5
Totals.......	12,673	12,451	9,987	11,323	11,608	100.0	100.0	100.0	100.0	100.0

MORTALITY FROM ALL CAUSES AND FROM TYPHOID FEVER, ACCORDING TO AGE OF DECEDENT

Infant mortality in America is a subject upon which much is written each year, and while some improvement is noted from year to year the number of children who die before they reach the age of five years is appalling. Of all the deaths at all ages from all causes occurring during the year, one quarter of them are children under five years old. Over 350,000 babies die annually in this country, most of them through ignorance, and private and public neglect, but typhoid fever is not a great contributing factor in this because of the very immaturity of the subject.

In Tables 10 and 11, and Plate V, the percentage distribution of deaths from all causes and from typhoid fever is shown. After passing the age of five years the percentage of deaths from all causes gradually rises without a break to an apex between the years of sixty and eighty, and then falls off abruptly. In the case of typhoid fever the most dangerous age period is from twenty to thirty years. Until the subject is ten years of age, and after he passes fifty, a relatively high degree of immunity obtains. Over three-quarters of all typhoid deaths occur between the ages of ten and fifty.

WHITE AND COLORED TYPHOID FEVER DEATH RATES

One-tenth of the population of the United States are colored. A large share of this population resides in the southern states, from which no vital statistics are available. In Table 12 statistics are given for the years 1911, 1912 and 1913 from seven states, having at present a total population around 27,000,000 and a colored population of about 1,800,000. These data are arranged to show the relative typhoid fever death rates among the white and colored population living in urban and rural districts.

How much greater the typhoid mortality is among the colored population is made clear, and it is shown that whereas the white rural typhoid death rate is 11 per cent in excess of the urban typhoid death rate, the colored rural typhoid death rate is 14 per cent in excess of the urban typhoid death rate. This difference is not particularly marked, but it is significant, nevertheless, as indicating that as regards rural sanitation the colored population is even worse off than is the white population.

PLATE V

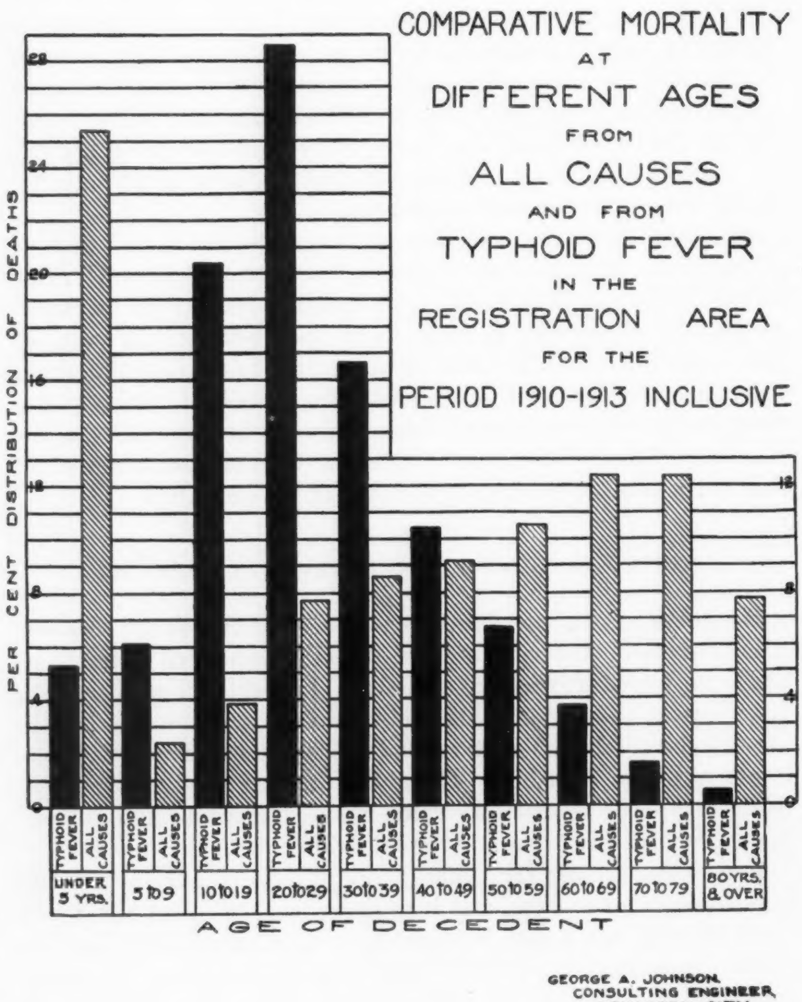

COMPARATIVE MORTALITY
AT
DIFFERENT AGES
FROM
ALL CAUSES
AND FROM
TYPHOID FEVER
IN THE
REGISTRATION AREA
FOR THE
PERIOD 1910-1913 INCLUSIVE
PER CENT DISTRIBUTION OF DEATHS
0
4
8
12
16
20
24
28
TYPHOID FEVER
ALL CAUSES
UNDER 5 YRS.
5 to 9
10 to 19
20 to 29
30 to 39
40 to 49
50 to 59
60 to 69
70 to 79
80 YRS. & OVER
AGE OF DECEDENT
GEORGE A. JOHNSON
CONSULTING ENGINEER
NEW YORK CITY.

TABLE 12

White and colored typhoid fever death rates in rural and urban districts (per 100,000 population living)

STATE	RACE	1911 Rural	1911 Urban	1912 Rural	1912 Urban	1913 Rural	1913 Urban	AVERAGE Rural	AVERAGE Urban
Indiana	White	26.5	27.2	20.7	28.6	23.4	26.8	23.5	27.5
	Colored	25.9	26.2	62.8	28.1	43.0	54.9	43.9	36.4
Kentucky	White	46.5	29.3	33.7	20.7	43.6	23.3	41.3	24.4
	Colored	70.7	56.1	49.1	67.9	69.1	44.9	63.0	56.3
Maryland	White	37.9	29.2	22.6	26.4	27.7	25.6	29.4	27.1
	Colored	65.7	39.0	49.2	33.1	70.5	52.5	61.8	41.5
Missouri	White	34.8	24.3	26.2	14.0	25.4	21.1	28.8	19.8
	Colored	51.6	41.6	70.7	24.6	35.0	36.8	52.4	34.3
North Carolina	White	66.9	67.7	36.4	31.5	49.2	52.5	50.8	50.6
	Colored	88.8	58.6	48.6	53.5	55.9	86.6	64.4	66.2
Ohio	White	22.6	22.6	16.6	19.1	24.7	22.1	21.3	21.3
	Colored	29.1	28.8	33.9	39.3	41.2	47.8	34.7	38.6
Pennsylvania	White	20.0	23.9	16.4	16.5	16.1	19.6	17.5	20.0
	Colored	32.3	21.5	14.5	15.8	27.5	34.3	24.8	23.9
Averages	White	36.5	32.0	24.7	22.4	30.0	23.7	30.4	27.2
	Colored	52.0	38.8	47.0	37.5	48.9	51.1	49.3	42.5

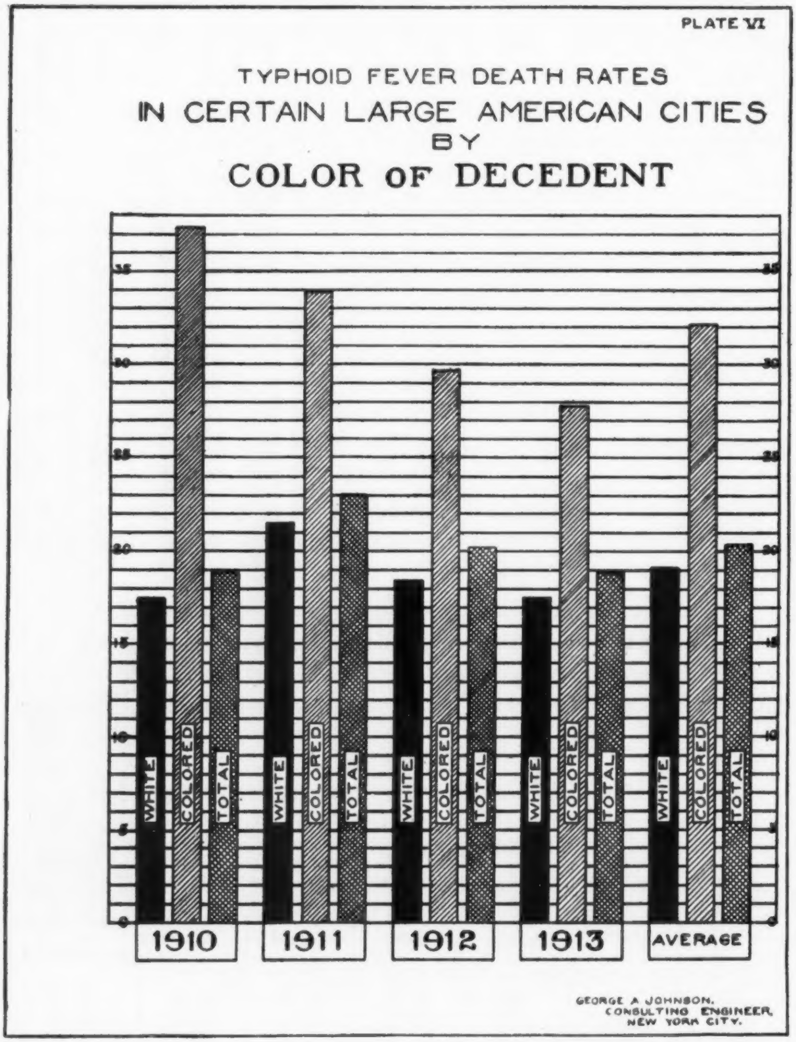
Table 13 and Plate VI show a digest of the statistics on typhoid fever among the white and colored populations of twenty-four well scattered large American cities, see Appendix, Tables 31 to 34 inclusive. The four-year survey of these data, 1910 to 1913, inclusive,

TABLE 13

White and colored typhoid fever death rates (average for four years—1910 to 1913 inclusive)

YEAR	DEATHS FROM TYPHOID FEVER		TYPHOID FEVER DEATH RATE PER 100,000 POPULATION LIVING			PER CENT WHICH WHITE DEATH RATE WAS OF TOTAL TYPHOID FEVER DEATH RATE
	White	Colored	White	Colored	Total	
1910	2415	354	17.5	37.3	18.8	93.1
1911	2519	364	21.5	33.8	23.0	93.5
1912	1656	295	18.4	29.6	20.1	91.5
1913	1704	293	17.5	27.8	18.8	93.1
	8294	1306	18.7	32.1	20.3	92.7

shows that on an average the typhoid fever death rate among the colored population of these twenty-four large cities was 72 per cent in excess of the white typhoid death rate. Due to the preponderant



white population, the total typhoid death rate is increased by the high colored rate by less than 9 per cent.

A somewhat peculiar phenomenon, and likewise encouraging

indication, is the fact that while the white typhoid death rate in these cities fell slowly during the four-year period, the decrease in the colored rate was even more pronounced, the annual percentage reductions, as compared with the year previous, being 9, 12 and 6, respectively. This savors of better general municipal sanitation in the residential districts of the lower classes.

HOW TYPHOID FEVER IS CONTRACTED

All typhoid fever is caused by a specific germ, the Bacillus typhosus, first discovered by Eberth in 1880 in the mesenteric glands and in the spleen of persons dying from typhoid fever.

Starting from the alimentary tract, which may be said to be its habitat, whether its host is actually suffering from typhoid fever or is a chronic carrier of the germ, it is discharged in the urine, feces, and, in rare cases, in the perspiration and the sputum of the host. The typhoid bacillus may now be said to be at large, and consequently a potential menace to the health of the public. The various ways in which well persons may receive the germ, and perhaps contract typhoid fever, are well nigh incapable of accurate listing, but in the following pages some of the more common easy avenues are mentioned.

TYPHOID INFECTION THROUGH DIRECT CONTACT

Typhoid fever, while not in a strict sense contagious, is unquestionably communicable, and a large share of the typhoid fever cases are caused by direct contact of a well person with a person suffering from this disease. The important rôle played by the typhoid carrier in this connection will be discussed under a separate heading.

Where others ministering to the wants of the typhoid patient soil their hands with the typhoid infected excreta, and later convey it to their own mouths, direct contact infection may result. Where those whose duty it is to attend to the excreta of typhoid patients, soil their hands with it, and do not carefully wash and sterilize them in consequence, and thereafter handle and contaminate the food and drink of others, or even the utensils from which they are consumed, indirect contact infection may follow. Even the use by well persons of towels soiled by others with typhoid matter can cause typhoid infection.

The person attendant on a typhoid patient must constantly be on guard against the possibility of infecting himself or others. He is constantly touching the patient, taking away his excretions, bathing him, and changing the bed linen which is almost certain to be infected. Freely granting all that anti-typhoid vaccine can do, the only way in which an attendant can be absolutely assured of freedom from self infection is to carefully wash and disinfect his hands after each contact with the patient; and it is most important that he keep his hands out of his own mouth. All instruments, dishes, cutlery and bed linen should be subjected to immediate disinfection after use by the patient, and, although it is almost never done, the attendant's clothing should be changed completely on leaving the room to come in contact with others.

Persons visiting the patient should first be cautioned not to come in actual contact with him, and it would be the height of good practice to provide each visitor with sterilized gloves, slippers and full length coat before entering the room. And yet, where the patient is cared for in his own home, how often other members of the family come in contact with him, and thereafter fail to exercise even the most elementary precautions. The sequential result often is a case of direct infection. Where several cases occur in the same family, all following some days after the first case, the evidence is strongly in favor of contact infection.

The spread of typhoid fever by contact is one of the most common modes of dissemination. As is well known, the discharge of the typhoid germs begins some ten days before the patient actually becomes ill, consequently it is obvious that by handling or using bedding, clothing, towels, food, and many other things used by others, he may be the cause of their infection with the disease of which he is about to suffer. Thus, within a few days or weeks, there often appear several cases of typhoid fever within the same house, the source of the infection being the single original patient.

Those attendant on a typhoid patient who fail to exercise the required measures of precaution, and to keep their hands and clothing free from such infectious material as may adhere to them when caring for the wants of the patient, in the pursuance of their other duties may contaminate the food and drink of others, and thus serve as the connecting medium between the sick and the well.

The limits to which this thought can be carried are terrifying. A member of the household contracts typhoid fever. The other

members of the household attend the wants of the patient and unwittingly carry infected material away from the bedside on their hands. Perhaps the sale of dairy products is one of the means of livelihood of that household, and so conceive that the person with contaminated hands attends to the preparation of the products for the market. The milk, and maybe the butter and cheese are thus contaminated, and all are admirable culture media for the typhoid germ. The infected products are distributed in several different families, and the original patient, through the carelessness of the well members of his household, thus serves as the originator of several other foci of the disease. It becomes a sort of endless chain. The same thing applies in a lesser sense where raw vegetables and fruits are sold or prepared for the table by one whose hands are soiled with typhoid infected excreta.

In practically every epidemic of typhoid fever secondary cases appear after the initial outbreak. When the original source of the primary infection has been located and eliminated, these secondary cases continue to appear. They usually come from contact infection. An investigation made in Washington in 1906–1907, showed that about 13 per cent of the cases obtained their infection from contact with other cases, and led to the following statement:

> This gives us our cue for one of the most important and practical measures to prevent the further spread of the infection. Every case of typhoid fever, every case of suspected typhoid fever, and every case of continued fever until the diagnosis is settled, should be treated as typhoid fever, isolated, and disinfection practiced so as to prevent the spread of the infection. If these measures are conscientiously and aggressively carried out they will largely diminish the amount of the disease in this or any other city. We must learn that a case of typhoid fever may be just as dangerous to a community as a case of small-pox, scarlet fever or cholera. The discharges should be disinfected as they leave the body and before they have a chance to contaminate the environment.

Perhaps the most striking instance of secondary infection was unearthed by Dr. E. O. Jordan while investigating the undue prevalence of typhoid fever in Winnipeg in 1900–1903. In the course of a house to house canvass of one district, by no means the worst, he found secondary cases in 56 per cent of the houses.

TYPHOID CARRIERS

When once a person has had typhoid fever, and has recovered, it frequently happens that it may become established in a chronic form, and the specific germ of the disease be discharged by the "carrier" for many years. The records are clear in showing that people have carried the germ for over fifty years, and all the time gave no external sign of having the disease.

Reliable investigators have estimated that 4 per cent of the convalescents from typhoid fever become chronic "typhoid carriers." One investigator figures that at the present time there are 20,000 persons in the United States, all apparently enjoying good health, who carry the germ of typhoid fever, and who must be looked upon as a threat against the public health. There are some 300,000 new cases of typhoid fever in the United States each year, and 4 per cent of these, representing the newly made carriers, amounts to 12,000, consequently the above figures of 20,000 would appear all too low an estimate of the number of chronic "typhoid carriers" in the United States at the present time.

The typhoid carrier is the keenest sort of menace when his or her occupation is in the line of purveying milk and other foods. A recent investigation of the employees of hotels and public restaurants in New York City disclosed the fact that some 4 per cent of the employees, whose duty it is to handle food and drink for consumption by others, are infected with some form of communicable disease.

Perhaps the most spectacular case of a typhoid carrier, due chiefly to the advertising it received, was that of "Typhoid Mary," a cook, who, during her active career, was the innocent cause of twenty-six cases of typhoid fever in seven different families. When the facts become known she was kept under enforced control until public clamor against such a proceeding resulted in her being set free. This was a splendid example of the failure of the general public to realize the truthfulness of Hutcheson's claim that

> That action is best which procures the greatest happiness for the greatest number.

While there are scores of cases on record, for the purposes of this paper only one specific case of the damage wrought by a typhoid carrier will be recited. This is taken from the Thirty-seventh

Annual Report of the State Board of Health of New Jersey. It appears that for a period of some fifteen years many cases of typhoid fever had occurred among the members of a certain farmer's family, and other persons intimately associated therewith, residing in Raritan Township, Monmouth County, and the source of the infection of these cases had never been definitely determined. On investigation the following history was procured:

During the summer of 1896 the farmer, his wife, three sons, two daughters and several employees resided on the place. The eldest son, then 16 years of age, left home to accept employment in a store in South River, and after an absence of several weeks he returned ill with what proved to be typhoid fever. There was no previous history of typhoid fever in this family nor on the farm.

Within the next few weeks the boy's father, then about 43 years old, his sister, then 6 years of age, and several employees on the place contracted the disease. After the son's recovery, he again left home and has not since that time resided on the farm. Subsequent to this original case, the well that had previously furnished water for potable purposes was filled up, as the result of a chemical analysis, and a new one was dug. Still other cases of typhoid fever continued to occur, from year to year, in persons residing at or working on the farm, with the result that further improvements were made in and about the house and buildings; and eventually a third well was procured far remote from any apparent sources of pollution. These changes were followed with additional cases of typhoid fever and during the summer of 1903 another son, then 19 years of age, suffered an attack of the disease. During the fall of 1908 this son was married and brought his wife to occupy a newly constructed dwelling on another portion of the farm, and in July, 1910, she contracted typhoid fever. In September, 1912, their three-year old son fell a victim to the disease.

Covering a period of sixteen years, dating from the original case brought to the farm during the summer of 1896, to the date of occurrence of the last case above referred to, 18 cases of typhoid fever are known to have occurred in persons who had either resided on the farm in question or who were closely associated with those who did.

Of the persons included among those in whom the above cases occurred there remained resident on the farm, at the time this inquiry began, the father and two daughters, living in the homestead, and the son together with his wife and child, occupying the house constructed in the year 1908. Two of the six persons named suffered from typhoid fever in 1895, one in 1903, one in 1910, one in 1912, and the sixth at some period of time during these years, the exact date not being definitely ascertained.

From the history procured there appeared no reason to suspect the water supply now in use in either of the two dwellings, nor to believe that other structural conditions about the well kept buildings and farm have been responsible for continuing the infection. On the other hand, it seemed more probable that some one of the persons who had suffered an attack of typhoid

fever during the year 1896 had become a chronic "carrier" and, as such, the source of infection of the subsequent cases.

As a preliminary step toward locating such a possible "carrier," specimens of blood for Widal reaction were taken from the following persons:

PERSON	AGE	HAD TYPHOID FEVER	DATE SPECIMEN WAS TAKEN	RESULT OF EXAMINATION
Father.......	59	August 1896	November 6, 1912	Positive
Daughter....	22	September 1896	November 6, 1912	Positive
Son..........	28	July 1903	November 6, 1912	Negative
Son's wife....	27	June 1910	November 6, 1912	Positive

Assuming that a positive blood reaction means that the body of the individual from whom it is taken then or has recently harbored the typhoid bacilli, the results above shown are rather remarkable, inasmuch as they indicate three typhoid "carrier" cases out of four persons whose blood was tested; two sixteen and one two years after recovery from an attack of the disease. It therefore appeared that at least two persons residing in the homestead on the farm had been constant or intermittent sources of infection for a period of sixteen years past, and that one "carrier" has existed in the new dwelling for more than two years past. It is quite probable that another daughter in the family, who gives a past history of malarial fever, but whose blood was not tested, may also have suffered from typhoid fever. The natural inference deduced from the data in hand up to this time was that the son's wife, who had typhoid fever in June, 1910, contracted the disease from a "carrier" case in the home of her father-in-law, where she frequently ate food, and that she subsequently infected her own child, who was ill with the disease during the month of September, 1912.

The results and significance of the blood examination were explained to the persons from whom the specimens had been taken and the desirability of continuing the investigation, by the examination of specimens of feces and urine, was pointed out. It was also explained that these examinations would be made by the State Board of Health without expense to the families concerned. The essential precautionary measures that typhoid "carriers" should observe were carefully gone over in detail, and the dire results that might follow disregard of scrupulous personal cleanliness and the safe disposal of all excretions from such individuals were particularly dwelt upon.

While the members of the affected family were naturally much disturbed by the realization of their predicament, and somewhat dismayed at the prospect that several of them might continue, for an indefinite period, to be sources of typhoid infection, the offer of assistance in carrying the inquiry to a satisfactory termination was rejected and no further specimens were furnished, nor did the persons whose blood gave a typhoid reaction seek remedial treatment.

Attention was next called to this family on April 14, 1913, while investigating a small but explosive outbreak of typhoid fever in the Borough of Keyport. In seven cases of the disease, occurring in six houses, the dates

of onset were found to have been about April 1st. As a result of a careful study of the individual cases, suspicion fell upon milk that had been supplied by a small local dealer. It appeared from the epidemiological study of this outbreak that the dealer distributed about 60 quarts of milk a day to a small number of families residing in the Borough of Keyport. Of this amount the dealer produced about 15 quarts daily and purchased from four nearby farms various amounts sufficient to meet his daily sales. No recent nor remote typhoid history was associated with any of the dairies then contributing to the supply. In checking up the dates to learn when the dealer began to take milk from each of these four farms, it appeared that one had been taken on about March 15, 1913, and a former contributor (of from 5 to 8 quarts a day) had been dropped on March 20th. The discontinued supply proves to have been obtained from the farm about which typhoid infection has centered for so may years, and upon which the three "carrier" cases referred to above were located.

According to information procured, the farmer and his son each kept one cow to supply milk for their respective families, and when the supply exceeded the amount required for home consumption the excess was disposed of to the milk distributor above referred to who had been taking this excess milk for sale in Keyport since going into business about one year before. Both cows were stabled in the barn at the homestead, and had been milked and cared for by the son prior to his departure with his family from the State on March 5, 1913.

Following the son's removal from the "typhoid-carrier farm" a hired man did the milking until the cow that had belonged to the son was sold, on or about March 20th, after which time the local dealer procured no more milk from this farm. On two or three occasions, just prior to the sale of this cow and some time between March 15th and 20th, the farmer, whose blood had given an absolute typhoid reaction, did the milking in order that the hired man should not be put to the inconvenience of coming from his home, a mile or more distant, for this express purpose on these particular occasions. It was some time between March 15th and 20th that infection of the cases of typhoid fever that occurred in Keyport took place.

For obvious reasons, it was not possible to definitely prove how and where the milk distributed by the dealer became infected, but the strong presumptive evidence is that it was the result of the infected farmer's obliging act in milking the cows on two or three occasions at about the time the infection occurred.

Justification for this assumption is to be found:

1. In that no typhoid history was revealed on the milk dealer's farm nor among any of those contributing to this supply except the one referred to above.

2. During the period of time that the son (whose blood did not give a Widal reaction) did the milking no infection of the milk appears to have occurred.

3. The hired man, who usually did the milking on the infected farm after the son's departure, had for years kept and milked several cows at his own home, and personally distributed milk to consumers, among whom no cases of typhoid fever occurred.

4. The farmer, whose blood gave an absolute typhoid reaction milked the cows on one or two occasions about the time that persons using this milk in the Borough of Keyport became infected.

The dealer who distributed the infected milk retired from the business as soon as it was shown that he had presumably, yet unknowingly, played a part in the spread of infection that resulted in ten cases of typhoid fever and two deaths, while the original source of infection that caused the outbreak evidently remains as potent a factor of danger as at any previous time.

Thus it is easy to understand the continuous menace which the chronic typhoid carrier is to the public at large, and it is very clear that there should be a registration system for them. They should be educated in the necessary precautionary measures to be taken, and so long as they are shown to be active disseminators of the typhoid germ they should be prohibited from engaging in vocations involving the handling of the food and drink of others, and should be required to report at stated intervals to the health authorities for examination. In other words, their personal habits should be a matter of continuous record so long as they are shown to be carriers of the typhoid germ.

INFECTION FROM CONTAMINATED FRUIT AND VEGETABLES

The farmer with an extensive truck garden is an object of rural envy. Very often this garden is fertilized entirely with the contents of the farmer's privy, although he is not always particular about that, not refusing to use the contents of his neighbor's privies if he can get them for nothing, as he often can. There may be the undisinfected excrement of typhoid patients in this material, but this not being known, or its significance understood, it is not wasted on that account. It is not difficult to conceive of typhoid infected lettuce, radishes, tomatoes, strawberries and other foods which are consumed raw, coming from such a garden. In far eastern countries human excrement is used very largely in the fertilization of truck farms, for other forms of natural fertilizers are not available, and artificial fertilizers are too expensive. It is noteworthy, however, that old foreign residents of those countries will not eat foods of this character unless they are grown by themselves. They know the danger in so doing.

In the sidewalk markets, seen in all cities and large towns, fruits and vegetables are exposed for sale. The word "exposed" is used advisedly, for without being exposed the insanitary house fly could

not speed to them from the filth of the nearby gutter, nor could the introspective housewife paw over the stock with hands perhaps soiled with the excrement of a typhoid sufferer in her home. After her comes another of clean habits who buys the stuff the other has handled and effectually contaminated, and later in her home there appears a case of typhoid fever, the source of infection of which naturally is obscure. This thought could be dwelt on indefinitely.

CONTAMINATED SHELLFISH

Oysters grow best in sewage polluted surroundings. Where they grow in clean, unpolluted territory they usually are dark in color, and lack the nice, fat, healthy appearance of the oyster which feeds on sewage. If grown in unpolluted waters the oysterman, to improve their bulk and appearance, transports them to a brackish estuary where they are "drinked" or "floated," and by this treatment become lighter colored and fat in appearance. An oyster filters many gallons of water each day, and in this way obtains its nourishment. If the water is sewage polluted, and very commonly it is, the oyster may take into its system as food myriads of typhoid germs. Such oysters, eaten raw, serve as admirable media for the transmission of typhoid germs from sick to well persons, and when pleasantly warmed through, as in the case of the only entirely acceptable form of stewed oysters, its value as a typhoid medium is but slightly lessened.

INFECTION THROUGH THE MEDIUM OF THE HOUSE FLY

The common house fly feeds voraciously on typhoid infected excreta, in the sick room or privy, and finding access to food and drink thus conveys on its feet the noisome, typhoid-infected filth from the sick to the well. It is really astonishing how slowly this perfectly obvious method of spreading typhoid fever is growing in the public mind. Among the lower classes it is generally unknown and unheeded, and even among the classes of higher intelligence the slogan "Swat the Fly" often falls upon unheeding ears, or is jocularly referred to as the new king of indoor sports.

Where there is a typhoid patient in a house, one of the quickest and surest ways of conveying the typhoid germ from the sufferer to the remainder of the family is to deposit the patient's undisin-

fected excrement in a privy or exposed place, and leave the rest to the flies, who can always be counted on at each meal time to forsake their repulsive explorations of fecal deposits for the family dinner table. And on their feet they bring to the table the typhoid germs, with which their abruptly, but only temporarily, deserted feast of filth is populated. A fly census taken in the privy at meal time would be most unproductive, for at those hours the fly population is being entertained by the human family at the dinner table.

The itinerant fish man and butcher, selling his wares from the tailboard of his wagon, always carries a sizable freight of house flies, and more than likely these uninvited passengers have only just left the family manure pile for the sake of a free ride and plenty of desirable food. To be sure, the wares of the butcher and fish man are cooked before consumption, but the flies are not, and usually with each sale a few flies are thrown in for good measure, to hover about the house until dinner is ready, then again to attack and contaminate the foods of which they temporarily have been deprived.

TABLE 14

General prevalence of flies in Brooklyn

WEEK ENDING	NUMBER OF FLIES CAUGHT DURING THE WEEK	WEEK ENDING	NUMBER OF FLIES CAUGHT DURING THE WEEK
June 1	7	August 24	281
June 8	36	August 31	99
June 15	142	September 7	344
June 22	287	September 14	497
June 29	872	September 21	521
July 6	1460	September 28	411
July 13	2348	October 5	182
July 20	2952	October 12	205
July 27	3813	October 19	180
August 3	4202	October 26	68
August 10	3015	November 2	59
August 17	1175		

In making a study of the seasonal prevalence of the house fly, Mr. D. D. Jackson, in 1907–1908, placed fly traps in different parts of New York City, and counted the number of flies caught in them. The results he obtained are instructive in showing the relatively small number of flies during the spring, the rapid increase in number with the advent of summer, and the slow decrease as colder

weather sets in. It is interesting to compare the results contained in Table 14 with those in Table 8 and Plates II and III, as indicating one reason for the high summer typhoid, and its slow decline in the late fall.

Another striking connection between the house fly and typhoid fever is the case of Jacksonville, Florida. Prior to 1910 the privies of the city were often open and accessible to the house fly. In 1911 these closets were all made flyproof, so far as possible. The effect of this improvement on the health of the people of Jacksonville is well shown by the marked decrease in the number of typhoid cases which followed the screening of the privies. These statistics are given in Table 15 and Plate VII.

TABLE 15

Typhoid fever cases in Jacksonville before and after making the privies fly proof

MONTH	1910	1912
	Before the privies were made fly-proof	After the privies were made fly-proof
January	8	9
February	0	5
March	4	7
April	6	4
May	41	11
June	41	18
July	109	10
August	82	5
September	14	7
October	15	8
November	7	2
December	2	4
Total	329	90

CONTAMINATED WELLS

The excreta of typhoid sufferers always should be thoroughly disinfected, but the cases are very numerous where it is either not done at all, because of the unpleasant labor involved, or done in a perfunctory manner. Where there is no water carriage system of sewerage these infected discharges are emptied in the privy or some other convenient place, sometimes being covered with earth, but more often not, and from these deposits, where favorable geological

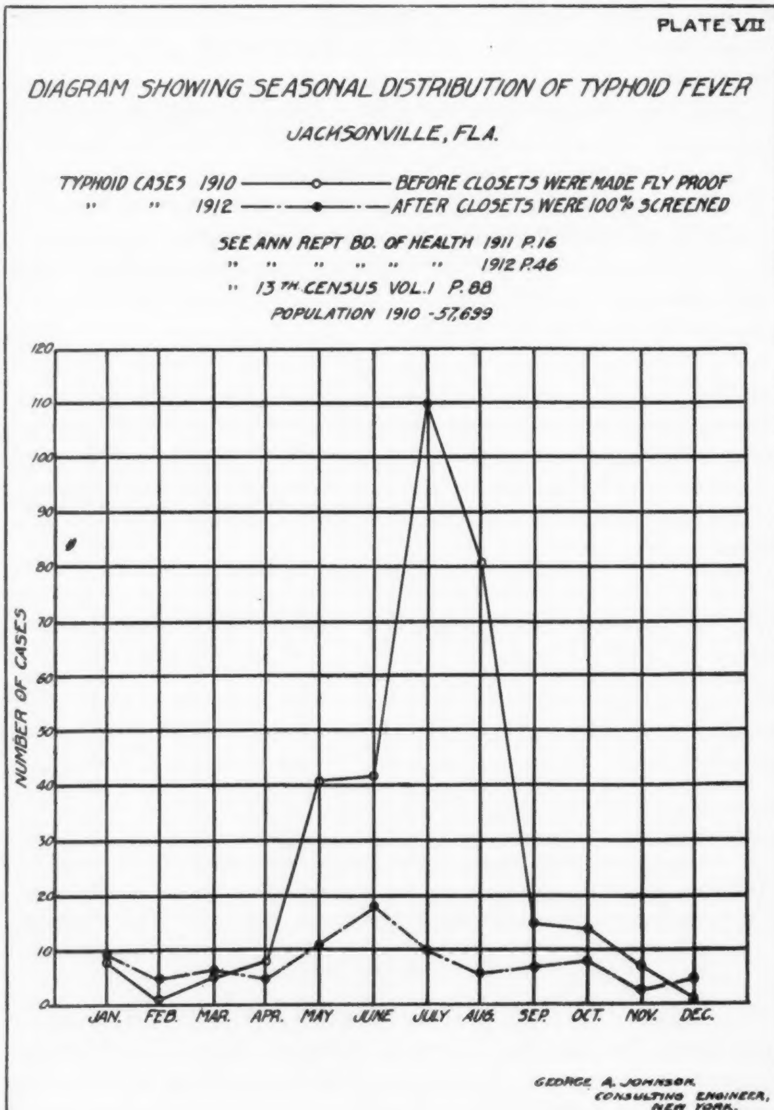


PLATE VII
DIAGRAM SHOWING SEASONAL DISTRIBUTION OF TYPHOID FEVER
JACKSONVILLE, FLA.
TYPHOID CASES 1910 BEFORE CLOSETS WERE MADE FLY PROOF
" " 1912 AFTER CLOSETS WERE 100% SCREENED
SEE ANN REPT BD. OF HEALTH 1911 P.16
" " " " " " 1912 P.46
" 13TH CENSUS VOL. I P. 88
POPULATION 1910 - 57,699
NUMBER OF CASES
120
110
100
90
80
70
60
50
40
30
20
10
0
JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEP. OCT. NOV. DEC.
GEORGE A. JOHNSON
CONSULTING ENGINEER,
NEW YORK.

and topographical conditions obtain, the typhoid germ easily finds its way through or over the ground into nearby wells, which serve as sources of drinking water for one or more families.

The attendants on a typhoid sufferer not infrequently regard the urine of such a patient as innocuous, and since it is less trouble it is emptied into a nearby sink or out of a back window. It has been positively demonstrated that the urine of a typhoid patient may contain as high as 1 to 500,000,000 typhoid germs per cubic centimeter, or from 5 to 25,000,000 in a single drop, and this is sufficient to show its very dangerous character, particularly in the contamination of dug wells.

A summary of the results of a large number of examinations made of wells located on farms in eastern and western United States showed that at least 60 per cent of the wells examined were contaminated with bacteria which are always identified with sewage. There is no doubt that a fair share of the annual typhoid grist comes from the consumption of polluted well waters, either through direct consumption, or through the contamination of milk and other foods which are brought in contact with them.

WHOLESALE POLLUTION OF PUBLIC WATER SUPPLIES

Where the house of the typhoid sufferer is provided with a convenient water closet, the temptation is great for the attendant to eschew the disagreeable task of effective disinfection, and the excreta, without such treatment, are summarily dumped therein to find unimpeded transit facilities to the nearest water way, from which others draw their water supplies. It may be that the sewage of such communities is subjected to some form of purification before it is allowed to flow into the nearest waterway, but no form of treatment used in any part of the world at all times actually destroys all of the disease germs in such sewages. It remains for those communities whose water supplies are thus polluted to purify them before consumption. If this is carefully done, all is well; if not, then there is always a heavy endemic toll of typhoid fever in those communities, the sodden monotony of which frequently is broken by a spectacular epidemic.

WATER BORNE TYPHOID FEVER EPIDEMICS

When the amount of typhoid fever in a community suddenly increases in a material degree the disease is said to be epidemic. Many cities have shown gradually increasing annual typhoid fever death rates and paid little or no attention to the matter, but when this additional harvest of typhoid fever deaths has occurred within a short space of time, the conviction usually is driven home that something is out of joint, and a flurry of investigation follows. This frequently shows that the public water supply, known to be "moderately" polluted, just prior to the outbreak received an unusual amount of disease bearing contamination; or that, although supposedly unpolluted, it became suddenly infected at that time.

In the former class of epidemics notable examples on record are those in the cities of Lowell and Lawrence, Massachusetts; Waterville and Augusta, Maine; Burlington, Vermont; Erie and Pittsburgh, Pennsylvania; Cleveland, Ohio; Chicago, Illinois; Milwaukee, Wisconsin; Minneapolis, Minnesota; Kansas City, Missouri, and Omaha, Nebraska. Details of many of these outbreaks can be found in Whipple's "Typhoid Fever." They all were traced positively and directly to the polluted water supply.

The epidemic typhoid in these cities during periods ranging from less than one year to nine years, in which from one to twelve distinct epidemics occurring in a single city, cost 6700 lives, and a loss in vital capital of $50,000,000, or roughly thirty-three times the cost of permanent prevention through filtration of the water supply. In all of these cities the officials well knew that the public water supply always was contaminated, or liable to contamination, by the sewage of other communities, yet they delayed taking the necessary steps until an epidemic, or a series of epidemics, forced them to action.

In the second class of epidemics, occurring in cities where the water supply was supposedly uncontaminated until the cause of a sudden outbreak of typhoid was traced direct to the water, notable examples on record are those at Plymouth, and Scranton, Pennsylvania; New Haven, Connecticut; Ithaca, New York, and Mount Savage, Maryland. While less fatal, numerically, these epidemics were more spectacular in their character, since the possibilities of contamination of the water supply seemed so remote. At Mount Savage a hillside spring supply became contaminated; at Scranton

a storage reservoir, holding over a thousand million gallons of water, suddenly became infected; at Plymouth and New Haven the water supply was taken from watersheds but sparsely populated, yet one case of typhoid on each of these watersheds resulted in epidemics of typhoid fever in those cities. The infected excreta which had been cast on the ground during the winter was washed by heavy rains into the streams from which the supplies were taken, and thus infected the water. The conditions surrounding the Ithaca epidemic were much the same.

In these few examples, and there are many more on record, the danger in unpurified water supplies stands forth prominently. Even in these single epidemics in five communities, two of which were large cities, four hundred lives were sacrificed to the insatiable appetite of the typhoid fever plague. This represents lost vital capital in the amount of $3,000,000, or fifty times the cost of pure filtered water at all of these places.

SEWAGE TREATMENT TO MINIMIZE WATER POLLUTION

The rural pollution, despite such local efforts as are made to minimize, or at least to control it, remains at all times a potent factor. Sewage treatment in the large community centers materially reduces the dangerous pollution, but it does not make safe for human consumption the waters of the streams into which the sewage effluent is discharged. Filtration of such waters is the only way to make them entirely safe.

Sewerage is helpful in municipal sanitation in that it removes the house drainage from the street gutters and causes the abolishment of the privies, and both of these are among the chief sources of maintenance of house fly life. Sewage purification aids the cause of general sanitation more than it really improves the hygienic quality of public water supplies. It tends to preclude the establishment and maintenance of offensive odors of putrefaction from polluted public waterways, and aids in the support of fish life. It prevents such bodies of water from becoming eyesores, but it does not make them drinkable without artificial purification.

The dream of the sewage treatment idealist was to make the sewage of cities innocuous, but the best disposal plants of size, even where sterilization is an important adjunct, have never succeeded in the complete and continuous destruction of disease germs in

sewage. It is not difficult to understand why. In the sewage collection systems of many cities there are some sewers which carry not only the house sewage but street wash as well. These sewers are provided with storm overflows which open automatically during heavy rains when the capacity of the sewer becomes overtaxed. The sewage thus bypassed direct to the stream is a combination of fresh house sewage and street wash. A little of this is often more dangerous, that is, contains more disease germs in a state of unimpaired virility, than the larger bulk of the sewage which flows through the main sewer to the disposal plant, and is there purified before it is finally discharged into the stream.

Then, too, all sewage treatment plants are liable to derangement at times, and such interruptions in the regular order of operation of the various parts of the plant cause the final effluent to enter the stream but partly purified. This is no secret in any city, although special bulletins are never posted declaiming the fact.

In the final analysis, sewage treatment works are necessary in keeping public water ways clean, that is, inoffensive to the senses of sight and smell. Further than this they do, of course, effect the destruction of a large proportion of the disease germs in the raw sewage. They cannot be depended upon for the complete annihilation of all such germs, therefore public waters receiving purified sewage are less dangerous only for the reason that they will likely contain fewer disease germs than waters receiving the sewage in its crude state. It remains for the water itself to be purified before it can be drunk with safety.

EFFECT OF WATER PURIFICATION ON THE TYPHOID FEVER DEATH RATE

Dr. Allen W. Freeman, Assistant Commissioner of Health of Virginia, recently said:[2]

> We have learned by sad experience that the measure of typhoid fever in any community is the measure of the distribution of human filth in that community, and that the dissemination of human excrement will inevitably result in the spread of typhoid fever . . . . The problem is no longer an investigative or scientific problem, but a problem of administration. When

[2] The Present Status of our Knowledge Regarding the Transmission of Typhoid Fever, Public Health Reports, issued by the United States Public Health Service, January 10, 1913.

the people of the United States wish to pay for absolute protection against typhoid fever it can be bought with the full assurance that the goods can be delivered. As physicians and sanitarians, we are most interested in the practical question, can typhoid fever be prevented? We know that it can. We know that our methods are certain, that they will yield the desired result in every case where they are properly applied. The problem remaining for solution is how to convince the American people that protection from typhoid fever is something worth spending money for.

Dr. Freeman estimates that in the northern part of the United States the purification of all water supplies would result in the reduction of the annual typhoid rate to a figure usually less than twenty per hundred thousand population, while in the south the purification of the water supply alone would seldom reduce the rate to less than fifty per hundred thousand, other measures, such as perfect sewering or rigid screening and supervision of dry closets, being required to bring down the rate to the point which could be reached in the north by water purification alone. Below this point, in the north and south alike, reduction must be attained by the thorough supervision of cases of illness, which means the requirement of morbidity returns and the prompt notification of all suspicious cases, protection of milk and other foods from typhoid contamination, elimination of flies and their breeding places, control of typhoid carriers, and the use of anti-typhoid vaccine whereever feasible.

Dr. Freeman's viewpoint is unquestionably sound, but in the broad analysis his estimates of what filtration would do are perhaps a little too low. For years it has been recognized that efficient filtration of the public water supply of a community will result in a reduction of from two-thirds to three-quarters in the typhoid fever death rate. Where the initial rate is high the percentage reduction following filtration of the water supply usually is correspondingly high, as noted particularly in the cities of Albany, Cincinnati, Columbus, Lawrence, Philadelphia and Pittsburgh. In these cities the average typhoid fever death rate for the five year periods before and after filtration, respectively, showed a reduction of 76 per cent, or a typhoid fever death rate per 100,000 population of seventy-nine reduced to nineteen. The combined result of water filtration in twenty representative cities showed that filtration was followed by an average reduction in the typhoid fever death rate of 65 per cent.

In southern cities it is difficult for filtration to make as favorable showing as in the north, for the reason that causes other than im-

pure water are more prevalent and active in the south. Particularly is this true with respect to the house fly and the open privy. The case of Jacksonville is enlightening on this point.

TABLE 16

Reduction in typhoid fever death rates in American cities following the filtration of their public water supplies (Averages for five years before and five years after filtration)

CITY	AVERAGE TYPHOID FEVER DEATH RATE		PER CENT REDUCTION IN TYPHOID FEVER DEATH RATES WHICH FOLLOWED THE FILTRATION OF THE PUBLIC WATER SUPPLY
	Before Filtration	After Filtration	
Albany, N. Y.	109	28	74
Charleston, S. C.	106	62	41
Cincinnati, O.	56	11	80
Columbus, O.	83	17	78
Harrisburg, Pa.	72	33	54
Hoboken, N. J.	18	13	28
Indianapolis, Ind.	46	28	39
Lawrence, Mass.	110	23	79
Louisville, Ky.	57	24	58
New Haven, Conn.	40	25	38
New Orleans, La.	39	26	33
Paterson, N. J.	29	9	69
Philadelphia, Pa.	63	20	68
Pittsburgh, Pa.	132	19	85
Providence, R. I.	19	13	31
Reading, Pa.	53	35	34
Scranton, Pa.	25	10	60
Springfield, Mass.	22	22	0
Washington, D. C.	55	31	43
Wilmington, Del.	35	24	31
Weighted averages	60	21	65

The raw water supplies of the south are no more badly polluted than those of the north, and filtration is quite as efficient, but the influence of the water borne typhoid on the typhoid fever death rate is deeply overcast by the high death rate emanating from sources of infection other than the water supply. Thus, in the list of cities just given, Charleston, Louisville, New Orleans and Washington have efficient filter plants, yet filtration of the water supply reduced the typhoid fever death rate by only 41 per cent.

Among sanitarians there appears to be little if any dissention from the view that modern filtration practices actually eliminate the water borne diseases, or typhoid fever and allied disorders at the very least. That is to say, where the plants are properly designed, well constructed, and intelligently operated, water filtration in practical terms is one hundred per cent hygienically efficient.

In Table 17 and Plate VIII some instructive statistics are presented to show how the urban typhoid fever death rate has been reduced as water filtration developed. The relationship between the two is strikingly proportional, and holds out every good promise for the future.

TABLE 17

Relationship between the increase in population supplied with filtered water and the decrease in the typhoid fever death rate in the registration cities of the United States

YEAR	POPULATIONS		PER CENT WHICH FILTERED WATER POPULATION WAS OF		
	Total for registration cities	Total in United States supplied with filtered water	Total population of United States	Total population registration cities	Typhoid fever death rate in registration cities
1900	21,477,000	1,860,000	2.4	8.7	36
1	22,146,000	2,400,000	3.1	10.8	34
2	22,679,000	2,700,000	3.4	11.9	37
3	23,221,000	3,100,000	3.8	13.3	38
4	23,724,000	3,800,000	4.6	16.0	35
5	24,729,000	4,300,000	5.1	17.4	30
6	26,342,000	5,400,000	6.7	20.5	33
7	27,145,000	6,300,000	7.2	23.2	32
8	28,501,000	7,500,000	8.4	23.3	25
9	29,655,000	8,900,000	9.8	30.1	21
1910	21,342,000	10,805,000	11.7	34.6	24
11	32,376,000	12,000,000	12.8	37.2	20
12	33,304,000	14,100,000	14.7	42.4	16
13	34,230,000	16,500,000	17.0	48.0	16

URBAN TYPHOID FEVER DEATH RATE IN THE UNITED STATES

In Table 18 all the available data are brought together in condensed form to show the average typhoid fever death rate among the urban population of the United States.

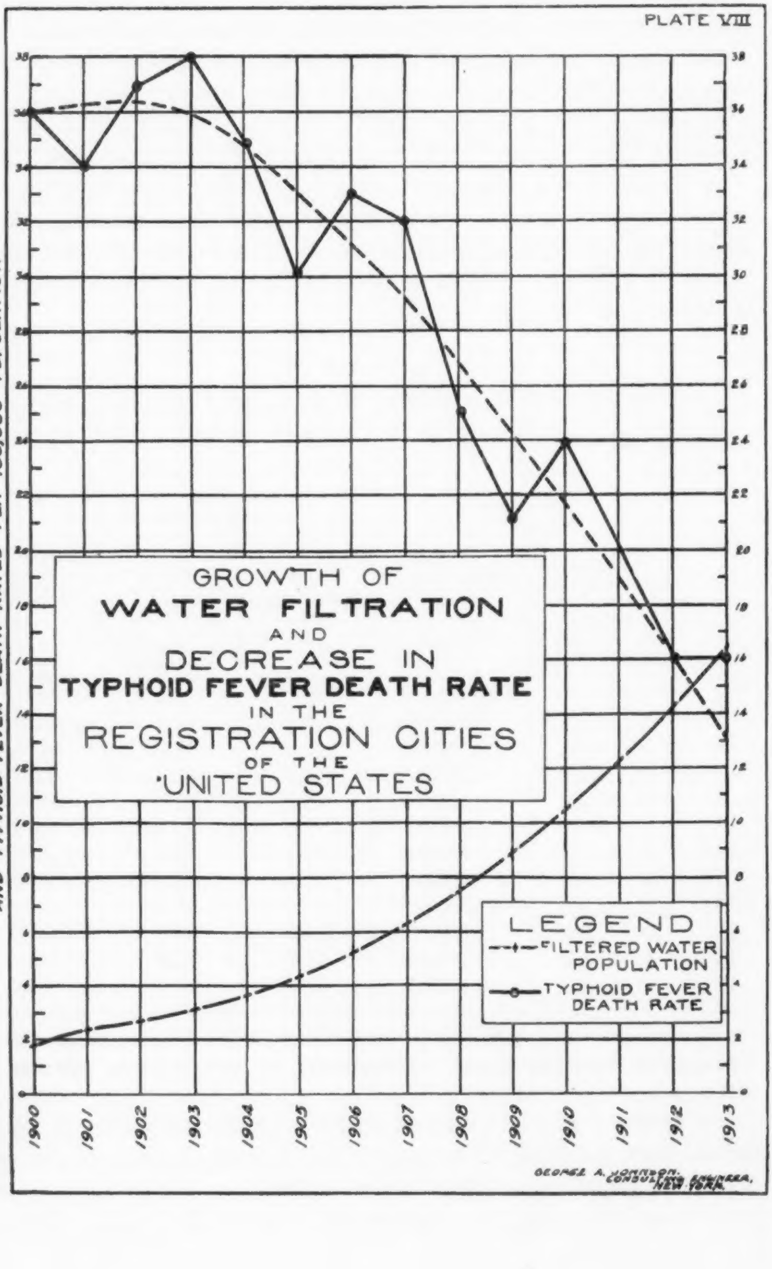


PLATE VIII
GROWTH OF
WATER FILTRATION
AND
DECREASE IN
TYPHOID FEVER DEATH RATE
IN THE
REGISTRATION CITIES
OF THE
UNITED STATES
MILLIONS OF PEOPLE SUPPLIED WITH FILTERED WATER
AND TYPHOID FEVER DEATH RATES PER 100,000 POPULATION
LEGEND
FILTERED WATER POPULATION
TYPHOID FEVER DEATH RATE
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
1911
1912
1913

TABLE 18

Semi-final analysis of the urban typhoid fever death rate in the United States

YEAR	REGISTRATION CITIES OF THE UNITED STATES	TOTAL SUPPLIED WITH FILTERED WATER	TOTAL FOR TWENTY REPRESENTATIVE CITIES WHICH ULTIMATELY ADOPTED FILTRATION	BALANCE IN REGISTRATION CITIES HAVING NO FILTRATION
		populations		
1900	21,477,000	1,860,000	4,038,000	19,617,000
1913	34,230,000	16,500,000	5,364,000	17,730,000
		Typhoid fever death rate		
1900	36	42	49	37
1913	17	14*	16	19
		Per cent reduction in typhoid death rate		
Between 1910 and 1913	53	67*	67	50

* Based upon actual experience noted in the case of the twenty representative cities.

The typhoid fever death rates in the southern states are uniformly higher than in the northern states. Reliable statistics are lacking from the former, and it is therefore difficult to estimate with accuracy the typhoid fever death rate in the country as a whole. In six of the nonregistration southern states, however, statistics are available from fourteen cities, with a total estimated population in 1913 of 1,444,000, and these are presented in Table 19.

TABLE 19

Typhoid fever death rates in registration cities in southern non-registration states in the year 1913

STATE	TOTAL POPULATION OF REGISTRATION CITIES	TYPHOID FEVER DEATH RATE IN REGISTRATION CITIES	ESTIMATED TOTAL URBAN POPULATION IN STATE
Alabama	254,000	39.4	1,100,000
Georgia	290,000	27.2	1,400,000
Louisiana	356,000	16.9	900,000
South Carolina	60,000	51.8	800,000
Tennessee	287,000	35.4	1,100,000
Texas	197,000	26.4	2,000,000
Totals and weighted averages	1,444,000	29.3	7,300,000

These data show that in 1913 the average typhoid fever death rate in these fourteen southern cities was 29.3 per 100,000 population, and in these six nonregistation states the estimated total urban population in 1913 was 7,300,000. We have already included the data for these fourteen cities in our figures given in Table 18, as showing the typhoid fever death rate in the registration cities of the United States, but by applying their average rate to the remainder of the urban population in these six nonregistration states, we may summarize as follows:

Summary to show the average typhoid fever death rate among the total urban population of the United States (all figures based on conditions in 1913)

	URBAN POPULATION	TYPHOID FEVER DEATH RATE PER 100,000 POPULATION
All registration cities	34,230,000	17
Balance in the six non-registration states	5,856,000	29
Balance in the United States	10,000,000	23
Weighted average		20

WHAT THE COMMON PURIFICATION OF PUBLIC WATER SUPPLIES WOULD DO

If all the urban population of the United States were supplied with filtered water or water of equal purity, the average urban typhoid fever death rate would be fourteen per 100,000. In making this important statement it is well to explain that this figure was obtained by estimating, on a basis of proportions, an average typhoid fever death rate of forty-three per 100,000 among the total urban population of the United States in 1900, or about the time when filtration began to show its effects on the public health of the country. A reduction of 67 per cent in the typhoid rate immediately following filtration has been amply demonstrated. Hence a residual rate of fourteen per 100,000 results.

It has just been shown that the average typhoid fever death rate among the total urban population of the United States in 1913 was twenty per 100,000, a fair figure for present day conditions. Purer filtered water supplies, or supplies of equal purity, would lower this rate to fourteen, representing among the urban popula-

tion a saving of 3000 lives annually, and forty-five thousand cases of typhoid fever. This represents an amount of vital capital equal to $22,500,000 annually, or, at 6 per cent, the interest on an investment of $375,000,000.

Of the 50,000,000 people representing the urban population of the United States, 20,000,000 are now supplied with filtered water. To build filtration works having a total daily capacity of 4000 million gallons daily, easily sufficient to provide pure water for the remaining 30,000,000 people, would not cost $100,000,000. To operate these works and pay all charges, including interest and sinking fund, would not cost more than $12,000,000 per year, or about one-half the present annual loss in vital capital. The remaining $10,500,000 per year in saved vital capital would make a substantial nucleus for a public health fund to be expended in general disease prevention work. It would represent 21 cents per capita per year for the entire urban population of the United States, and if expended solely for typhoid prevention would go a long way toward effecting the elimination of this plague.

In addition it must not be forgotten that the filtration of the water supplies of all the urban population of the country would reflect favorably on the health tone of the rural population, or such of it as comes in touch with the larger communities through periodical visits. This benefit is not measurable in precise figures, but what pure water in one city may mean to the health of a nearby community was never better demonstrated than in the case of Allegheny and Pittsburgh. They always were practically one city, and now are so incorporated. Allegheny has only quite recently received pure water from the Aspinwall filter plant, but as soon as filtered water was supplied to Pittsburgh the typhoid fever death rate in Allegheny, for no other apparent reason, began to decrease. For the three year periods before and after filtration of of the water supply of Pittsburgh, the average typhoid fever death rates in Allegheny, located just across the river, were ninety-one and thirty-six per 100,000 population, respectively. This was a reduction of 60 per cent, obviously due to the large number of the residents of Allegheny working in Pittsburgh and drinking the pure filtered water of that city.

CONCLUSIONS

We are told by physiologists that in all mammals except man the span of life is five times the period of growth. Primitive man, who lived before the day of physiologists, doubtless existed much as other mammals, and, judging from the Holy Writ, and assuming that a biblical year represented one complete revolution of the earth around the sun, must have been cleverer than the other mammals in fending off the reaper of life.

It was not so long ago that we read of the compassionate methods of the Patagonians in dealing with old age, it appearing to be the custom to lean a stout club against the domicile of one who had lived beyond his usefulness, the inference thus being made plain. Descendants of our North American aborigines quite often claim an age in excess of five score years, although such examples are fast disappearing before the vitiating influences of modern civilization.

It seems to be quite true that the higher the plane of civilization the greater the untoward effects of insanitary living. The great plagues of ancient, medieval and modern times gathered their harvest of lives alike from rich and poor, just and unjust, clean and unclean. The susceptibility to cholera and typhoid fever of a person who bathes every day appears to be just as great as in a person whose ablutions occur at far less frequent intervals.

And yet, a man who follows the practice of daily bathing is not likely to have really unclean habits, nor his hands serve as shelters for disease germs. Distinctly dirty people, however, in a measure, seem to become immune to some forms of disease, and often pass their lives unharmed in the midst of filthy conditions, which would spell prompt infection to those of a higher order of intelligence if transplanted to such an environment.

The rapid promotion of ideal methods of living is not possible. It can only be effected by a slow transitional advancement. Custom is hard to uproot, and probably the greatest obstacles are presented where the democratic form of government prevails. Liberty and freedom are often misinterpreted to mean excess, and the exercise of self-emolumentalization at the expense of others. True sanitation is that which benefits, not a single individual or a community, but the public at large. A city may pompously declaim the possession of a modern system of water purification at its front door, and at its back door be fouling the water supply of its neighbor with its

sewage. It has done for itself, taking no heed of its neighbors' welfare. "Sufficient unto the day" is its motto.

Individual freedom is measured by the control which governs personal convenience and desire. Attainment is measured by sacrifice and restraint. An individual or a city has no more moral or legal right deliberately to pollute a public water supply than deliberately to commit homicide. Typhoid fever accounts for twenty thousand lives each year in America largely through a misconceived idea of what constitutes personal liberty. Granting that the pollution of public waters cannot be entirely prevented, obviously it is the duty of every city to make pure such waters before they are delivered to the consumers. This is preparedness quite as important as preparedness for war. It is a measure of protection against disease and death, just as preparedness for war is protection against loss of life and property.

The greatest need of a nation for its own betterment is not so much more laws, as the rigid enforcement of laws already existing. If the wide array of laws against the pollution of public waters were enforced, grossly offensive conditions would never exist. If laws were enforced making it an imprisonable offence on the part of the officials of a city to allow the use of a contaminated water, or the existence of privies and cesspools, or slack garbage collection and disposal, or unclean streets and gutters, the health tone of the country at large would be immeasurably improved. It would cost money, and it would place restraints upon the individual citizen which at first would be resented, but a generation of such training would result in the complacent observance of the new order of affairs. If every public spirited citizen could be made to realize that liberty does not mean license to injure another for the sake of his own conveniences, and if he would understand that human happiness is based on the precept that the greatest good is that which conveys the greatest benefit to the greatest number, he would break away from his shell of custom, bigotry and selfish concern, and work for the general good of mankind. That is true liberty, true religion and true citizenship.

TABLE 20

Typhoid fever death rates in large

CITY	STATE	POPULATION					TYP																
		1880	1890	1900	1910	1915 (Est.)	1880	1881	1882	1883	1884	1885	1886	1887	1888	1889	1890	1891	1892	1893	1894	1895	1896
Albany	N. Y.	30,800	94,900	94,200	100,250	110,000					91	115	180	128	114	100	65	113	52	61	55	170	102
Allegheny	Pa.	78,600	105,300	130,000	150.000	*	56	122	140	72	47	72	63	116	107	104	139	90	157	145	88	196	50
Atlanta	Ga.	37,400	65,500	89,900	154,800	200,000	67	173	129	184	112	86	58	127	186	79	152	119	107	89	68	90	88
Baltimore	Md.	332,300	434,400	509,000	558,800	583,000	59	57	47	7	41	41	38	39	39	45	57	34	43	49	48	37	40
Birmingham	Ala.				132,700	180,000																	
Boston	Mass.	362,800	448,500	560,900	680,600	746,900	42	56	57	52	56	39	34	44	40	43	35	34	29	31	29	32	31
Bridgeport	Conn.	27,600	48,900	71,000	102,100	115,000	36	45	30	6	33	34	0	43	19	18	6	16	13	22	3	10	18
Buffalo	N. Y.	155,100	255,700	352,400	423,700	460,000		68	71	35	43	23	29	35	29	30	41	49	36	40	63	29	22
Cambridge	Mass.	52,700	70,000	91,900	104,800	112,000	19	39	31	28	41	27	34	32	41	37	24	22	21	22	36	15	37
Camden	N. J.	41,700	58,300	75,900	94,500	105,000	60	75	114	86	73	89	82	96	102	161	141	55	62	61	65	97	47
Charleston	S. C.	50,000	55,000	55,800	58,800	72,000	112	113	105	110	83	56	66	81	56	74	102	51	49	44	44	60	80
Chicago	Ill.	503,200	1,099,900	1,698,600	2,185,300	2,437,500	34	101	75	53	48	62	56	41	38	44	92	172	122	58	37	38	52
Cincinnati	Ohio	255,100	296,900	325,900	363,600	400,000	70	71	56	51	56	42	54	142	71	49	69	62	40	44	55	39	52
Cleveland	Ohio	160,100	261,400	381,800	560,700	720,000	44	99	68	65	60	34	51	52	47	74	69	50	59	52	29	36	43
Columbus	Ohio	51,600	88,100	125,600	181,500	207,000										44	74	53	47	46	45	52	44
Dayton	Ohio	38,700	61,200	85,300	116,600	130,000	36	92	29	41	42	42	35	35	28	31	20	30	43	69	73	81	64
Denver	Col.	35,600	106,700	133,900	213,400	235,000								141	161	188	268	90	57	62	51	36	75
Des Moines	Iowa	22,400	50,100	62,100	86,400	100,000														41	53	54	25
Detroit	Mich	116,300	205,900	285,700	465,800	600,000			54	50	58	49	39	65	46	32	19	34	94	42	28	23	22
Duluth	Minn.	800	33,100	53,000	78,400	92,000									280	158	126	208	116	144	181	250	237
Elizabeth	N. J.	28,200	37,800	52,100	73,400	81,400	21	28	24	43	41	31	27	20	34	24	53	13	27	19	24	32	18
Erie	Pa.	27,700	40,600	52,700	66,500	80,000	14	59	64	20	19	31	32	20	24	51	71	72	57	35	38	46	41
Evansville	Ind.	29,300	50,800	59,000	69,600	92,500								85	66	71	77	100	56	67	64	178	49
Fall River	Mass.	49,000	74,400	104,900	119,300	122,600	71	63	97	60	46	54	49	70	68	68	280	64	34	76	39	34	27
Grand Rapids	Mich.	32,000	60,200	87,600	112,600	125,000											50	69	81	105	52	46	12
Harrisburg	Pa.	30,800	39,400	50,200	64,200	75,000											76	107	76	110	70	57	20
Hartford	Conn.	42,000	53,200	79,800	98,900	125,000	31	63	68	28	61	45	44	16	51	50	56	71	81	48	52	57	45
Hoboken	N. J.	31,000	43,600	59,400	70,300	75,000	25	22	82	41	69	58	54	42	38	58	44	31	33	21	35	22	41
Indianapolis	Ind.	75,100	105,400	169,200	233,700	270,000													44	89	43	104	56
Jersey City	N. J.	120,700	163,000	206,400	267,800	300,900	26	63	121	49	85	71	61	54	74	83	98	100	72	66	54	95	85
Kansas City	Kas.	3,200	38,300	51,400	82,300	100,000													17	30	23	29	17
Kansas City	Mo.	55,200	132,700	163,800	248,400	300,000																	
Lawrence	Mass.	39,200	44,700	62,600	85,900	90,000	69	124	77	69	46	41	55	110	111	125	154	120	127	103	48	31	19
Los Angeles	Cal.	11,200	50,400	102,400	319,200	550,000					89			127	119	100	38	52	38	59	65	43	36
Louisville	Ky.	123,200	161,100	204,700	223,900	235,000	66	107	92	44	114	109	81	81	88	92	88	79	69	78	82	69	70
Lowell	Mass.	59,500	77,700	95,000	106,300	111,000	37	86	80	76	62	72	72	125	79	91	161	98	95	67	60	38	43
Lynn	Mass.	38,300	55,700	68,500	89,300	96,000	68	60	65	49	45	30	29	32	23	12	19	19	18	19	19	20	41
Manchester	N. H.	32,600	44,100	57,000	70,100	80,000			155	64	53	58	32	48	30	38	38	39	23	31	42	41	38
Memphis	Tenn.	33,600	64,500	102,300	131,100	146,000				59	87	62	70	78	77	59	54	68	30	31	55	42	40
Milwaukee	Wis.	115,600	204,500	285,300	373,900	418,900	37	47	31	24	30	27	29	30	40	27	40	32	29	34	25	25	18
Minneapolis	Minn.	46,900	164,700	202,700	301,400	355,000									127	76	39	59	49	82	56	47	36
Nashville	Tenn.	44,300	71,200	80,900	101,400	121,000	133	84	57	63	83	65	39	52	62	64	50	63	59	49	38	55	44
Newark	N. J.	136,500	181,100	246,100	347,500	405,000	53	36	66	59	55	58	51	49	43	73	107	71	77	31	20	19	27
New Bedford	Mass.	26,800	40,800	62,400	96,700	110,000	7	43	42	33	73	21	79	17	21	47	13	19	38	63	27	18	27
New Haven	Conn.	62,900	81,300	108,000	133,600	145,000	29	37	36	49	60	24	34	31	48	30	29	22	30	32	31	35	29
New Orleans	La.	216,100	242,400	287,100	339,100	400,000		30	33	23	25	16	13	14	19	17	21	24	20	15	28	41	32
New York	N. Y.	1,897,700	2,487,800	3,437,200	4,766,900	5,625,000	23	36	31	35	28	26	25	25	22	23	22	23	22	21	18	18	16
Oakland	Cal.	34,600	48,700	67,000	150,200	225,000	58				32	30	31	35	47	39	45	54	39	89	25	30	29
Omaha	Neb.	30,518	140,500	102,600	124,100	155,000												17	13	16	30	23	14
Paterson	N. J.	51,000	78,300	105,200	125,600	34,500						28	28	24	24	26	23	23	18	39	32	23	50
Peoria	Ill.	29,300	41,000	56,000	66,900	74,000																	
Philadelphia	Pa.	847,200	1,047,000	1,293,700	1,549,000	1,700,000	59	74	73	64	71	64	64	63	78	72	63	64	40	41	32	40	34
Pittsburgh	Pa.	156,400	238,600	321,600	533,900	600,000	136	152	156	105	69	78	68	125	95	95	132	101	101	112	57	77	62
Portland	Me.	33,800	36,400	50,100	58,600	63,000								8	15	25	7	29	14	33	46	47	26
Portland	Ore.	17,600	46,400	90,400	207,200	277,200																	
Providence	R. I.	104,900	132,100	175,600	224,300	247,700	50	36	128	115	46	38	45	33	84	47	30	46	37	35	47	30	25
Reading	Pa.	44,300	58,700	79,000	96,100	103,000	49	80	52	38	32	28	42	35	45	45	55	48	45	39	51	54	52
Richmond	Va.	63,600	81,400	85,000	127,600	155,000	61	110	78	77	176	73	38	44	39	55	93	60	74	61	35	35	15
Rochester	N. Y.	89,400	133,900	162,600	218,100	245,000	23	28	31	40	48	30	29	32	44	30	32	37	51	41	12	29	17
St. Louis	Mo.	350,500	451,800	575,200	678,000	750,000	40	58	45	41	42	31	30	28	30	32	30	37	106	34	33	19	22
St. Paul	Minn.	41,500	133,200	163,100	214,700	275,000	87	200	160	105	116	55	73	141	119	82	56	48	41	42	26	28	29
San Antonio	Tex.	20,600	37,700	53,300	96,600	120,000	72	103	104	198	156	99	83	85	107	72	114	84	78	54	100	76	31
San Francisco	Cal.	234,000	299,000	342,800	416,900	500,000	36	38	62	65	58	44	50	23	33	55	44	42	32	32	38	34	26
Savannah	Ga.	30,700	43,200	54,200	65,100	85,000																	
Scranton	Pa.	45,800	72,200	102,000	129,900	160,000	26	43	25	54	51	67	34	18	60	38	34	52	59	42	36	55	39
Seattle	Wash.	3,500	42,800	80,700	237,200	310,000																	
Somerville	Mass.	24,900	40,200	61,600	77,200	83,000	28	31	30	46	27	36	9	33	48	19	122	31	32	29	28	21	51
Spokane	Wash.				104,400	120,000																	
Springfield	Mass.	33,300	44,200	62,100	88,900	105,000	48	79	63	78	49	58	31	42	63	44	200	36	84	36	33	18	21
St. Joseph	Mo.	32,400	52,300	63,000	77,400	85,000													29		34	28	38
Syracuse	N. Y.	51,800	88,100	108,400	137,200	155,000					19	22	35	28	35	27	33	45	36	37	43	32	31
Toledo	Ohio	50,100	81,400	131,800	168,500	187,000	36	41		36		26	14	34	35	37	47	27	40	27	32	40	36
Trenton	N. J.	29,100	57,500	73,300	96,800	104,000	17	62	62	47	59	29	30	40	24	39	19	26	25	31	26	17	24
Troy	N. Y.	56,700	61,000	61,000	76,800	80,000					21	60	82	82	57	76	41	79	44	61	57	64	46
Utica	N. Y.	33,900	44,000	56,400	74,400	86,000	50	31	39	24	24	26	26	32	17	28	25	24	44	11	25	16	18
Washington	D. C.	177,600	230,400	278,700	331,100	355,000	53	84	65	61	77	66	73	78	86	95	112	80	91	84	89	94	58
Wilkes-Barre	Pa.	23,300	37,700	51,700	67,100	74,000																	
Wilmington	Del.	42,500	61,400	76,500	87,400	100,000	57	100	116	70	96	51	49	69	57	51	90	56	46	68	43	40	22
Worcester	Mass.	58,300	84,700	118,400	146,000	170,000	53	35	45	28	30	28	7	18	3	31	18	21	22	34	33	26	14

* Included in Greater Pittsburgh.

TABLE 20

Typhoid fever death rates in large American cities

TYPHOID FEVER DEATH RATE PER 100,000 POPULATION LIVING																								
1886	1887	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
180	128	114	100	65	113	52	61	55	170	102	88	100	87	51	21	32	20	18	19	20	20	11	19	15
63	116	107	104	139	90	157	145	88	196	50	65	56	105	93	75	122	123	123	127	136	97	40	28	42
58	127	186	79	152	119	107	89	68	90	88	69	62	86	61	77	69	66	61	70	50	64	47	44	43
38	39	39	45	57	34	43	49	48	37	40	39	37	30	37	29	42	35	37	36	34	41	31	23	42
																				39	71	64	44	51
34	44	40	43	35	34	29	31	29	32	31	33	34	30	26	25	24	21	23	20	22	10	26	14	11
0	43	19	18	6	16	13	22	3	10	18	23	10	11	21	26	24	14	17	13	10	13	13	13	9
29	35	29	30	41	49	36	40	63	29	22	21	28	25	27	27	34	35	24	24	24	29	21	23	20
34	32	41	37	24	22	21	22	36	15	37	13	15	22	16	9	11	11	16	12	18	10	10	9	12
82	96	102	161	141	55	62	61	65	97	47	55	43	38	16	16	23	14	21	18	18	22	13	11	17
66	81	56	74	102	51	49	44	44	60	80	72	131	109	127	86	80	64	59	53	84	50	46	56	56
56	41	38	44	92	172	122	58	37	38	52	29	38	26	20	30	45	32	20	17	18	18	15	12	14
54	142	71	49	69	62	40	44	55	39	52	32	36	37	37	55	62	43	80	41	71	46	19	13	6
51	52	47	74	69	50	59	52	29	36	43	23	32	29	54	35	36	115	50	15	20	19	13	12	19
			44	74	53	47	46	45	52	44	25	26	22	42	48	37	38	148	85	45	38	110	17	17
35	35	28	31	20	30	43	69	73	81	64	24	21	36	31	34	44	24	27	22	28	38	16	24	18
	141	161	188	268	90	57	62	51	36	75	50	31	38	42	49	61	56	30	41	68	67	58	24	28
							41	53	51	25	34								18	16	16	30	18	32
39	65	46	32	19	34	94	42	28	23	22	15	17	19	18	21	23	20	18	21	22	28	22	19	20
		280	158	126	208	116	144	181	250	267	96	49	38	94	74	54	65	54	45	46	41	56	51	76
27	20	34	24	53	13	27	19	24	32	18	15	13	17	8	28	27	21	19	8	17	14	23	20	19
32	20	24	51	71	72	57	35	38	46	41	27	13	34	34	17	25	34	49	17	47	77	61	29	39
	85	66	71	77	100	56	67	64	178	49	28	48	66	63	27	43	28	40	43	38	34	34	39	33
49	70	68	68	280	64	34	76	39	34	27	33	20	11	14	26	11	23	11	11	8	18	13	14	13
				50	69	81	105	52	46	12	18	32	30	42	36	51	42	62	49	39	30	30	17	26
				76	107	76	110	70	57	20	17	32	40	48	66	63	104	59	69	66	48	50	29	33
44	16	51	50	56	71	81	48	52	57	45	29	45	48	44	44	16	22	13	17	33	19	19	10	19
54	42	38	58	44	31	33	21	35	22	41	17	14	30	17	26	10	16	20	14	17	27	12	10	16
						44	89	43	104	53	43	28	38	44	33	45	51	68	30	39	29	26	22	30
61	54	74	83	98	100	72	66	54	95	85	20	34	15	21	16	20	15	19	20	20	14	10	8	12
						17	30	23	29	17	19	32	33	52	58	62	88	65	75	56	91	53	75	95
												25	31	36	46	38	80	43	61	38	40	35	23	43
55	110	111	125	154	120	127	103	48	31	19	16	18	32	22	19	20	28	18	23	20	30	24	22	16
	127	119	100	38	52	38	59	65	43	36	29									18	23	19	18	12
81	81	88	92	88	79	69	78	82	69	70	48	58	60	58	46	60	60	62	49	68	79	49	43	31
72	125	79	91	161	98	95	67	60	38	43	19	26	18	18	20	18	33	20	19	7	9	24	11	21
29	32	23	12	19	19	18	19	19	20	41	28	22	19	19	14	13	18	24	23	15	17	20	11	17
32	48	30	38	38	39	23	31	42	41	38	20	25	21	11	17	15	18	21	19	14	14	30	17	11
70	78	77	59	54	68	30	31	55	42	40	34	22	38	35	52	39	41	46	34	42	35	33	41	28
29	30	40	27	40	32	29	34	25	25	18	12	16	17	21	22	15	17	14	23	30	26	17	21	46
		127	76	39	59	49	82	56	47	36	81	42	35	39	59	27	41	40	24	33	26	18	20	58
39	52	62	64	50	63	59	49	38	55	44	59	27	62	48	43	51	70	55	71	74	85	62	53	48
51	49	43	73	107	71	77	31	20	19	27	19	17	27	20	24	20	23	14	14	18	24	12	11	13
79	17	21	47	13	19	38	63	27	18	27	42	27	26	35	31	36	50	21	8	10	13	23	23	22
34	31	48	30	29	22	30	32	31	35	29	26	36	26	26	94	39	37	27	43	54	30	34	20	18
13	14	19	17	21	24	20	15	28	41	32	50	64	54	40	50	44	41	37	33	30	56	31	25	32
25	25	22	23	22	23	22	21	18	18	16	16	21	16	21	21	20	17	17	16	15	17	12	12	12
31	35	47	39	45	54	39	89	25	30	29	14	13	36	20	12	23	21	43	36	26	28	18	7	13
					17	13	16	30	23	14	19	31	25	23	24	22	11	17	25	28	24	22	31	89
28	24	24	26	23	23	18	39	32	23	50	50	33	46	23	23	34	22	7	14	4	11	10	5	7
64	63	78	72	63	64	40	41	32	40	34	33	49	73	35	35	47	73	55	51	75	60	36	22	17
68	125	95	95	132	101	101	112	57	77	62	63	68	107	144	124	141	136	139	108	141	135	53	13	12
	8	15	25	7	29	14	33	46	47	26	24	72	30	32	29	29	32	28	42	16	19	38	24	55
												22	23	27	21	36	36	26	35	25	22	24	20	23
45	33	84	47	30	46	37	35	47	30	25	15	22	24	23	25	21	20	15	20	19	8	16	12	17
42	35	45	45	55	48	45	39	51	54	52	34	65	33	50	53	66	32	33	26	40	47	54	37	32
38	44	39	55	93	60	74	61	35	35	15	24	31	44	88	52	72	73	54	45	47	41	50	24	22
29	32	44	30	32	37	51	41	12	29	17	23	14	18	19	17	12	12	16	12	17	16	12	9	14
30	28	30	32	30	37	106	34	33	19	22	21	17	23	29	33	40	52	38	23	18	16	15	15	13
73	141	119	82	56	48	41	42	26	28	29	16	26	18	22	14	14	10	14	11	21	17	12	20	20
83	85	107	72	114	84	78	54	100	76	31	30	35	43	90	62	65	62	50	44	29	51	33	41	50
50	23	33	55	44	42	32	32	38	34	26	19	17	51	41	25	30	25	31	24	—	57	27	17	15
												37	35	30	29	44	54	79	40	41	84	25	25	24
34	18	60	38	34	52	59	42	36	55	39	24	14	25	29	34	20	18	11	17	11	76	11	11	14
												30	31	30	31	33	37	37	36	20	48	22	23	14
9	33	48	19	122	31	32	29	28	21	51	21	18	24	15	19	8	14	18	13	14	17	12	9	10
												52	46	65	52	47	88	80	86	98	38	40	32	32
31	42	63	44	200	36	84	36	33	18	21	35	24	24	27	28	19	23	15	27	21	29	29	14	15
						29		34	28	38	28	12	34	7	14	14	8	12	8	12	14			39
35	28	35	27	33	45	36	37	43	32	31	24	43	18	29	19	8	18	18	17	10	16	15	12	28
14	34	35	37	47	27	40	27	32	40	36	34	24	30	39	32	35	30	37	46	45	36	40	31	37
30	40	24	39	19	26	25	31	26	17	24	37	30	45	31	19	40	60	43	25	35	79	52	32	50
82	82	57	76	41	79	44	61	57	64	46	33	73	76	155	57	49	36	50	51	34	28	35	22	20
26	32	17	28	25	24	44	11	25	16	18	15	21	18	25	16	17	18	18	13	27	19	20	15	7
73	78	86	95	112	80	91	84	89	94	58	50	61	61	78	61	79	49	47	48	52	36	39	33	25
																				31	45	23	14	37
49	69	57	51	90	56	46	68	43	40	22	33	35	60	47	41	61	95	51	36	46	40	25	30	38
7	18	3	31	18	21	22	34	33	26	14	15	11	16	27	22	14	15	6	21	11	14	10	8	16

1909	1910	1911	1912	1913	Averages				Per cent reduction			
					1880 to 1889	1890 to 1899	1900 to 1909	1910 to 1913	1880-9 to 1890-9	1890-9 to 1900-9	1880-9 to 1900-9	1900-9 to 1910-13
19	15	18	18	27		89	23	19		74.2		17.4
28	42	39	*	*	90	109	96	*	+21.1	11.9	+6.7	—
44	43	56	35	22	120	93	61	39	22.5	34.4	49.2	36.1
23	42	26	22	24	48	41	34	28	14.6	17.1	29.2	17.6
44	51	44	38	36				42				
14	11	8	9	8	46	32	21	9	30.5	34.4	54.3	57.2
13	9	4	8	6	26	13	16	7	26.9	+23.1	35.5	56.3
23	20	25	11	15	42	35	27	18	16.7	22.9	35.9	33.3
9	12	4	4	9	33	23	12	7	30.3	47.8	63.7	41.7
11	17	9	11	19	94	66	17	14	29.8	74.2	82.0	17.5
56	56	41	54	52	86	74	70	51	14.0	5.4	18.6	27.2
12	14	10	7	10	55	66	23	10	+20.0	65.2	58.2	56.5
13	6	11	7	7	66	47	47	8	28.8	0.0	28.8	83.0
12	19	14	6	14	59	42	37	13	28.8	11.9	37.3	64.8
17	17	14	19	19		43	61	17		+41.8		71.2
24	18	18	17	18	41	46	29	18	+12.2	27.1	29.3	37.9
24	28	17	13	14		76	50	18		34.2		64.0
18	32	25	10	13				20				
19	20	16	19	29		31	21	21		32.3		0.0
51	76	23	23	24		147	58	36		60.6		38.3
20	19	8	15	14	29	23	18	14	20.7	21.7	38.0	22.2
29	39	191	12	17	33	43	39	65	30.3	9.3	+18.2	+66.7
39	33	21	35	44		73	39	33		46.7		15.4
14	13	15	16	9	65	61	15	13	6.2	75.5	76.9	13.3
17	26	25	31	18		49	40	25		18.4		37.5
29	33	17	13	16		60	60	20		0.0		66.7
10	19	20	13	23	46	53	24	19	15.2	54.7	91.3	20.8
10	16	18	8	12	49	29	17	13	40.9	41.4	65.3	23.5
22	30	26	17	24			39	24				38.4
8	12	8	8	11	60	55	16	10	20.3	71.0	76.8	37.5
75	95	59	29	29			67	53				20.9
23	43	24	12	22			44	25				43.2
22	16	12	13	13	83	67	23	13	19.3	65.7	72.3	43.5
18	12	13	12	12		45	25	12		44.4		52.0
43	31	25	19	23	87	70	57	24	19.6	18.6	34.5	50.6
11	21	6	9	11	78	63	18	12	19.2	71.5	77.0	33.3
11	17	10	6	14	41	22	17	12	46.4	22.7	58.6	29.4
17	11	10	11	8		32	18	10		43.8		44.5
41	28	61	56	34		41	40	45		2.5		+11.1
21	46	19	23	11	32	25	21	25	21.9	16.0	34.4	+16.0
20	58	11	11	12		53	33	23		37.8		30.3
53	48	51	29	37	70	51	61	41	30.0	+19.6	15.7	32.8
11	13	10	7	8	54	41	18	9	24.1	56.7	66.7	50.0
23	22	23	18	10	38	30	25	18	21.0	16.7	34.3	28.0
20	18	23	24	13	38	30	40	19	21.0	+33.3	+ 5.3	52.5
25	32	30	13	17		35	39	23		10.2		41.0
12	12	11	10	7	27	19	17	10	35.0	10.5	37.1	41.2
7	13	13	19	12		37	23	14		26.4		30.1
31	80	17	12	7			23	34				+32.0
5	7	5	7	8		34	15	7		44.1		53.3
22	17	14	12	16	68	47	49	14	30.9	+ 4.3	28.0	71.4
13	12	10	6	10	108	88	113	12	18.5	+35.2	+4.6	
24	55	35	38	15		33	28	35		15.1		+20.0
20	23	18	17	7			27	16				40.8
12	17	14	10	11	62	32	18	13	50.0	42.0	71.0	27.7
37	32	23	28	59	44	48	44	35		8.3		25.0
24	22	17	15	20	75	47	55	18	37.3	+14.9	26.7	67.2
9	14	11	12	9	34	27	14	11	20.6	25.9	58.8	21.4
15	13	10	13	17	38	34	28	13	10.4	17.6	26.3	53.5
20	20	10	9	9	114	33	15	12	71.5	54.6	86.8	20.0
41	50	53	41	21	108	64	52	41	40.7	18.7	51.8	21.2
17	15	16	14	16	46	33	31	15	28.2	6.1	32.7	51.6
25	24	43	29	43			45	35				22.2
11	14	12	9	9	42	38	24	11	9.4	36.9	42.9	54.1
23	14	10	8	5			32	9				71.9
9	10	8	6	7	31	37	14	8	+19.4	62.2	54.8	42.8
32	32	37	17	7			63	23				63.5
14	15	18	17	21	56	51	23	18	8.8	55.0	59.0	21.7
	39	32	14	27				28				
12	28	15	16	13		34	16	18		53.0		+11.1
31	37	22	31	42		34	37	33		+ 8.8		10.7
32	50	44	39	21	41	28	42	38	31.7	+50.0	+2.4	9.5
22	20	27	19	16		57	52	20		8.8		61.5
15	7	12	6	11	29	22	19	9	24.1	13.4	34.4	52.7
33	25	22	23	16	74	78	52	24	+ 5.4	33.3	29.8	53.8
14	37	12	17	13				20				
30	38	28	30	23	72	49	47	30	31.8	4.1	34.7	36.2
8	16	7	3	3	28	21	15	7	24.9	27.8	46.5	53.3

TABLE 21

Typhoid fever deaths in the registration states, seasonal distribution (1910)

STATE	JAN.	FEB.	MCH.	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
California	21	19	24	27	31	55	43	50	55	49	47	39
Colorado	10	16	6	11	6	14	23	34	44	85	69	19
Connecticut	5	6	7	6	6	9	7	22	24	32	26	15
Dist. Columbia	3	4	6	5	5	4	6	10	13	8	8	5
Indiana	52	33	36	35	29	26	43	127	177	173	121	67
Maine	14	3	11	12	9	6	12	17	26	16	14	11
Maryland	25	25	28	25	13	16	25	72	100	79	72	48
Massachusetts	20	30	15	24	25	28	27	48	70	52	49	33
Michigan	32	43	43	30	27	22	29	74	106	120	86	55
Minnesota	28	57	72	40	15	19	21	56	106	108	96	50
Montana	3	1	4	7	2	10	5	23	31	34	22	9
New Hampshire	3	2	5	3	4	2	2	7	6	2	6	4
New Jersey	13	12	19	21	20	33	33	45	59	49	34	33
New York	91	92	97	74	66	72	100	142	185	174	168	136
North Carolina*	6	2	4	1	7	19	49	37	32	26	18	8
Ohio	74	60	65	68	67	41	68	145	202	233	167	124
Pennsylvania	130	124	138	125	91	78	80	208	275	284	208	151
Rhode Island	4	3	7	3	0	1	8	8	11	11	11	7
Utah	4	1	4	6	3	6	13	10	30	26	19	17
Vermont	5	5	1	6	2	3	1	5	4	10	5	3
Washington	22	10	12	9	17	11	24	45	44	45	50	35
Wisconsin	55	31	46	29	37	46	38	34	56	60	67	45

* Includes only municipalities having populations of 1000 or over in 1900.

TABLE 22

Typhoid fever deaths in the registration states, seasonal distribution (1911)

STATE	JAN.	FEB.	MCH.	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
California	40	33	23	26	35	39	43	33	43	45	44	26
Colorado	18	10	8	11	8	21	32	41	30	34	28	11
Connecticut	7	12	3	4	4	4	15	23	22	37	15	8
Dist. Columbia	6	4	4	3	8	2	5	11	7	6	8	11
Indiana	42	42	35	46	30	29	76	109	90	99	76	54
Kentucky	39	41	64	43	49	83	145	167	116	133	107	82
Maine	10	11	13	12	9	8	9	11	14	12	12	14
Maryland	22	11	23	18	22	19	25	78	89	84	73	27
Massachusetts	12	13	20	16	15	17	18	35	49	43	42	31
Michigan	40	42	50	44	35	34	44	52	56	64	47	39
Minnesota	21	18	23	20	10	11	17	24	23	37	52	27
Missouri	49	40	43	37	31	63	126	177	141	160	129	63
Montana	7	3	1	5	6	7	8	9	9	14	5	6
New Hampshire	13	5	2	5	3	0	3	4	8	8	5	7
New Jersey	22	28	16	15	23	15	32	30	42	32	29	31
New York	97	90	94	80	78	75	116	167	154	148	117	104
North Carolina	10	4	5	1	7	33	57	40	34	38	23	10
Ohio	81	59	66	58	53	52	71	108	158	174	144	77
Pennsylvania	143	176	125	101	92	89	88	174	199	223	168	138
Rhode Island	1	0	2	2	4	2	4	12	7	9	4	6
Utah	9	3	4	4	4	2	3	7	10	15	9	4
Vermont	4	1	3	0	6	3	2	3	8	6	1	7
Washington	23	14	7	5	14	22	19	25	32	22	30	10
Wisconsin	32	20	14	28	23	19	21	25	24	32	48	25

TABLE 23

Typhoid fever deaths in the registration states, seasonal distribution (1912)

STATE	JAN.	FEB.	MCH.	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
California	29	19	26	25	25	36	55	57	42	44	47	35
Colorado	5	5	4	5	8	7	12	9	29	24	14	10
Connecticut	7	4	8	7	13	7	13	13	16	14	9	15
Dist. Columbia	8	2	1	4	2	2	10	9	15	12	8	6
Indiana	29	43	41	32	35	32	33	70	97	107	80	46
Kentucky	49	44	34	43	54	31	71	93	91	127	88	67
Maine	15	9	6	9	8	5	4	9	13	9	7	9
Maryland	26	16	22	23	8	7	31	44	54	48	39	49
Massachusetts	18	10	12	15	15	26	20	29	33	34	30	27
Michigan	40	34	50	49	41	40	44	43	54	68	34	42
Minnesota	24	16	18	17	20	18	14	22	20	29	21	9
Missouri	42	35	51	28	32	35	49	98	127	121	92	61
Montana	7	2	1	8	2	2	4	8	10	3	4	6
New Hampshire	4	6	1	2	5	3	0	2	4	3	2	6
New Jersey	22	22	14	13	11	19	19	51	34	36	33	35
New York	109	64	69	71	83	73	77	121	138	143	86	73
North Carolina	7	2	4	6	1	14	24	25	30	15	15	12
Ohio	58	58	81	55	56	44	54	91	107	112	101	76
Pennsylvania	131	110	99	81	62	65	92	126	148	171	119	106
Rhode Island	2	0	1	1	4	3	2	5	7	11	5	3
Utah	2	1	2	1	0	6	4	5	13	12	8	3
Vermont	6	3	6	2	4	4	3	3	5	1	1	2
Washington	7	16	9	11	10	3	14	12	27	20	17	13
Wisconsin	47	31	35	24	25	16	14	10	31	28	21	27

TABLE 24

Typhoid fever deaths in the registration states, seasonal distribution (1913)

STATE	JAN.	FEB.	MCH.	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
California	29	19	18	19	25	34	47	51	43	51	55	33
Colorado	6	7	4	2	7	8	9	22	22	32	16	15
Connecticut	4	7	6	3	8	6	17	23	23	13	15	8
Dist. Columbia	4	4	4	2	3	5	7	9	2	11	2	4
Indiana	26	26	26	28	32	26	48	115	95	128	85	58
Kentucky	52	52	47	31	36	65	131	153	136	119	111	65
Maine	6	4	8	7	10	10	3	2	14	12	12	3
Maryland	19	19	27	10	19	28	48	82	63	55	43	30
Massachusetts	12	22	11	9	17	15	24	37	47	40	23	22
Michigan	44	31	35	37	31	28	42	47	72	68	62	42
Minnesota	19	16	16	9	6	6	16	15	23	50	36	23
Missouri	42	30	24	32	34	37	84	158	131	108	85	55
Montana	5	6	7	6	3	3	6	5	14	14	13	13
New Hampshire	6	3	1	3	1	3	8	2	6	5	10	4
New Jersey	14	10	14	10	16	15	28	36	44	39	31	8
New York	53	46	52	45	64	48	72	105	126	168	121	99
North Carolina	8	4	5	10	8	21	46	45	34	23	13	11
Ohio	51	51	55	67	77	65	106	176	181	177	106	79
Pennsylvania	92	84	65	81	105	97	111	173	201	196	137	128
Rhode Island	3	4	4	2	0	5	1	3	9	10	4	3
Virginia	26	19	30	15	30	70	109	106	118	99	44	43
Utah	0	2	2	3	2	4	12	10	10	20	10	15
Vermont	1	3	3	2	1	0	3	0	3	4	3	5
Washington	5	4	9	2	5	6	9	13	32	17	15	22
Wisconsin	23	17	19	21	21	12	12	15	24	22	15	16

TABLE 25

Typhoid fever deaths in the registration states, seasonal distribution (average for years 1910–1913 inclusive)

STATE	ESTIMATED AVERAGE POPULATION	JAN.	FEB.	MCH.	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
California	2,478,000	30	23	23	24	29	41	47	48	46	47	48	33
Colorado	828,000	10	9	5	7	8	13	19	27	31	44	32	14
Connecticut	1,138,000	6	7	6	5	8	7	13	20	21	25	16	12
Dist. Columbia	340,000	5	4	4	4	4	3	7	10	12	9	7	6
Indiana	2,721,000	37	36	35	35	31	28	50	105	105	127	90	56
Kentucky*	2,322,000	47	46	48	39	46	60	116	138	114	126	102	71
Maine	748,000	11	7	9	10	9	7	7	10	17	12	11	9
Maryland	1,307,000	23	18	25	19	15	18	32	69	76	61	57	38
Massachusetts	3,429,000	15	19	15	16	18	21	22	37	50	42	36	28
Michigan	2,454,000	39	38	44	40	34	31	40	54	72	80	57	44
Minnesota	2,112,000	23	27	32	21	13	14	17	29	43	56	51	27
Missouri*	3,335,000	44	35	39	32	32	45	90	144	133	130	102	60
Montana	391,000	5	3	3	6	3	6	6	11	16	16	11	9
New Hampshire	433,000	7	4	2	3	3	2	3	4	6	5	6	5
New Jersey	2,612,000	18	18	16	15	18	21	28	41	45	39	32	27
New York	9,320,000	88	73	78	70	73	67	91	134	151	158	123	103
North Carolina	373,000	8	3	4	5	6	22	44	37	32	25	17	10
Ohio	4,835,000	66	57	67	62	63	51	75	130	162	174	129	89
Pennsylvania	7,867,000	124	124	107	97	88	82	93	173	206	220	158	131
Rhode Island	556,000	2	2	3	2	2	3	4	7	8	10	6	5
Utah	384,000	4	2	3	3	2	5	8	8	16	18	12	10
Vermont	358,000	4	3	3	3	3	2	2	3	5	5	3	4
Virginia†	2,129,000	26	19	30	15	30	70	109	106	118	99	44	43
Washington	1,211,000	14	11	9	7	11	11	16	24	34	26	31	20
Wisconsin	2,363,000	39	25	29	25	26	23	21	21	34	36	38	28

* 1911–1913 inclusive.

† 1913

TABLE 26

Typhoid fever deaths in large American cities, seasonal distribution (1910)

CITY	JAN.	FEB.	MCH.	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
Baltimore, Md.	7	13	10	4	2	8	8	34	46	41	37	25
Boston, Mass.	2	3	1	2	7	1	5	8	16	7	17	7
Buffalo, N. Y.	7	10	2	8	10	2	4	11	5	10	8	10
Chicago, Ill.	21	12	17	14	13	14	22	33	44	36	48	26
Cincinnati, O.	2	1	1	2	3	1	4	4	8	4	1	1
Cleveland, O.	10	6	5	13	7	2	4	4	15	15	10	10
Detroit, Mich.	4	6	7	2	4	3	5	20	22	12	14	9
Jersey City, N. J.	0	0	2	0	1	2	2	5	8	5	5	1
Los Angeles, Cal.	1	4	1	4	1	5	5	4	5	6	5	5
Milwaukee, Wis.	22	15	18	12	17	28	17	9	12	10	9	3
Minneapolis, Minn.	13	31	42	23	5	2	4	11	21	10	11	5
Newark, N. J.	2	1	2	3	2	2	4	8	10	5	4	3
New Orleans, La.	5	8	7	7	5	13	12	13	14	9	7	7
New York, N. Y.	35	28	31	24	26	39	53	65	65	78	63	49
Philadelphia, Pa.	47	31	24	21	12	12	8	16	31	35	14	21
Pittsburgh, Pa.	7	11	19	12	10	10	8	15	13	17	10	17
St. Louis, Mo.	5	4	9	3	9	2	5	12	20	12	14	8
San Francisco, Cal.	1	2	5	6	5	10	3	9	10	6	6	2
Washington, D. C.	3	4	6	5	5	4	6	10	13	8	8	5

TABLE 27

Typhoid fever deaths in large American cities, seasonal distribution (1911)

CITY	JAN.	FEB.	MCH.	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
Baltimore, Md.	11	3	5	8	7	8	4	27	29	27	19	8
Boston, Mass.	2	3	5	3	3	3	4	6	11	8	10	2
Buffalo, N. Y.	6	12	12	7	7	4	11	15	13	7	12	3
Chicago, Ill.	16	17	15	12	20	17	25	27	25	26	19	26
Cincinnati, O.	3	3	4	1	1	3	6	6	5	3	6	2
Cleveland, O.	8	3	4	9	5	8	3	7	18	8	7	2
Detroit, Mich.	4	6	2	5	5	4	12	10	9	10	5	6
Jersey City, N. J.	1	0	0	1	0	3	1	5	3	2	1	3
Los Angeles, Cal.	4	1	2	3	3	3	2	2	6	5	6	3
Milwaukee, Wis.	6	4	4	8	6	3	10	8	4	3	15	4
Minneapolis, Minn.	1	2	5	1	1	1	0	2	2	5	12	5
Newark, N. J.	1	3	0	2	2	2	4	4	6	7	3	4
New Orleans, La.	7	3	11	2	9	16	17	14	6	10	6	6
New York, N. Y.	28	21	23	18	26	32	55	85	80	65	57	48
Philadelphia, Pa.	18	16	17	15	11	10	16	30	29	23	19	26
Pittsburgh, Pa.	16	15	12	8	4	12	8	11	14	8	19	12
St. Louis, Mo.	5	4	6	3	4	8	18	23	14	11	13	4
San Francisco, Cal.	8	5	1	3	7	6	0	1	11	8	10	5
Washington, D. C.	6	4	4	3	8	2	5	11	7	6	8	11

TABLE 28

Typhoid fever deaths in large American cities, seasonal distribution (1912)

CITY	JAN.	FEB.	MCH.	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
Baltimore, Md.	11	6	11	10	3	4	15	22	19	11	9	19
Boston, Mass.	5	2	1	2	1	8	3	9	9	9	4	4
Buffalo, N. Y.	8	2	1	5	9	4	4	3	3	2	3	8
Chicago, Ill.	11	7	8	18	8	14	10	23	24	20	13	14
Cincinnati, O.	1	2	1	5	4	2	1	6	3	3	0	2
Cleveland, O.	2	0	0	4	5	3	5	3	4	8	4	3
Detroit, Mich.	3	5	1	6	6	1	10	15	10	19	4	8
Jersey City, N. J.	0	1	1	1	0	4	2	2	2	4	3	2
Los Angeles, Cal.	2	2	3	7	5	6	3	13	3	6	7	1
Milwaukee, Wis.	24	13	16	6	9	6	5	1	9	3	4	7
Minneapolis, Minn.	3	4	1	5	5	2	1	4	5	3	5	0
Newark, N. J.	2	5	1	2	2	3	0	7	0	1	3	4
New Orleans, La.	2	2	0	4	1	7	2	6	7	2	8	8
New York, N. Y.	42	30	24	20	17	35	38	66	78	66	44	27
Philadelphia, Pa.	40	14	10	11	11	12	25	22	22	15	9	14
Pittsburgh, Pa.	7	8	10	5	7	5	6	8	6	6	3	1
St. Louis, Mo.	2	3	5	3	3	3	8	15	11	12	8	3
San Francisco, Cal.	7	5	1	2	1	6	11	8	4	5	3	6
Washington, D. C.	8	2	1	4	2	2	10	9	15	12	8	6

TABLE 29

Typhoid fever deaths in large American cities, seasonal distribution (1913)

CITY	JAN.	FEB.	MCH.	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
Baltimore, Md.	6	12	8	3	6	9	15	23	22	19	8	6
Boston, Mass.	4	8	4	0	1	2	3	5	11	14	5	2
Buffalo, N. Y.	6	3	3	4	7	3	5	7	5	13	6	7
Chicago, Ill.	7	18	12	13	16	15	8	22	24	36	44	28
Cincinnati, O.	3	2	2	1	2	2	4	3	3	4	0	1
Cleveland, O.	3	2	5	8	12	5	6	10	11	11	8	7
Detroit, Mich.	8	12	5	11	15	10	16	13	25	15	15	8
Jersey City, N. J.	1	0	2	2	3	4	3	4	6	2	3	1
Los Angeles, Cal.	3	3	3	1	3	1	6	2	4	8	10	6
Milwaukee, Wis.	3	6	5	6	4	3	5	1	4	4	3	2
Minneapolis, Minn.	1	1	4	2	2	1	5	1	5	4	7	7
Newark, N. J.	1	0	3	0	1	2	6	5	6	5	4	0
New Orleans, La.	4	2	3	1	0	5	8	13	7	4	8	5
New York, N. Y.	13	15	19	14	14	16	26	38	54	75	50	29
Philadelphia, Pa.	14	5	9	13	29	32	26	44	26	20	21	18
Pittsburgh, Pa.	7	6	7	5	8	5	9	13	19	10	5	15
St. Louis, Mo.	9	3	3	8	2	4	14	19	19	18	15	8
San Francisco, Cal.	6	3	1	4	5	9	10	5	7	5	9	7
Washington, D. C.	4	4	4	2	3	5	7	9	2	11	2	4

TABLE 30

Typhoid fever deaths in large American cities, seasonal distribution. (Averages for years 1910–1913 inclusive)

CITY	ESTIMATED AVERAGE POPULATION	JAN.	FEB.	MCH.	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
Baltimore, Md.	567,000	9	9	8	6	5	7	11	26	29	25	18	15
Boston, Mass.	700,000	3	4	3	2	3	4	4	7	12	10	9	4
Buffalo, N. Y.	437,000	7	7	5	6	9	3	6	9	7	8	7	7
Chicago, Ill.	2,265,000	16	14	13	14	17	15	16	26	29	30	31	24
Cincinnati, O.	385,000	2	2	2	2	3	2	4	5	5	3	2	1
Cleveland, O.	588,000	6	3	3	9	7	4	5	6	12	11	7	5
Detroit, Mich.	498,000	5	7	4	6	7	4	11	15	17	14	10	8
Jersey City, N. J.	279,000	1	0	1	1	1	3	2	4	5	3	3	2
Los Angeles, Cal.	358,000	2	2	2	4	3	4	4	5	5	6	7	4
Milwaukee, Wis.	398,000	14	10	11	8	9	10	9	5	7	5	8	4
Minneapolis, Minn.	317,000	5	9	13	8	3	2	2	4	8	6	9	4
Newark, N. J.	366,000	1	2	2	2	2	2	3	6	5	4	4	3
New Orleans, La.	348,000	4	7	5	4	4	10	10	12	8	6	7	7
New York, N. Y.	5,011,000	30	24	24	19	21	31	43	64	69	66	54	38
Philadelphia, Pa.	1,593,000	30	16	15	15	16	17	19	28	27	23	16	20
Pittsburgh, Pa.	547,000	9	10	12	8	7	8	8	12	13	10	9	11
St. Louis, Mo.	707,000	5	4	6	4	5	4	11	17	16	13	12	6
San Francisco, Cal.	430,000	5	4	2	4	5	8	6	6	8	6	7	5
Washington, D. C.	340,000	5	4	4	4	4	3	7	10	9	9	7	7

TABLE 31

White and colored typhoid fever death rate (1910)

CITY	DEATHS FROM TYPHOID FEVER		TYPHOID FEVER DEATH RATE PER 100,000 POPULATION LIVING			PER CENT WHICH WHITE DEATH RATE WAS OF TOTAL TYPHOID DEATH RATE
	White	Colored	White	Colored	Total	
Atlanta, Ga.	58	20	56.3	38.5	50.1	111.3
Baltimore, Md.	193	42	40.7	49.6	42.0	97.0
Birmingham, Ala.	40	26	50.0	49.8	49.5	101.0
Boston, Mass.	75	1	11.4	7.4	11.3	101.0
Chicago, Ill.	289	11	13.5	25.0	13.7	98.7
Cincinnati, O.	30	2	8.7	10.0	8.8	98.9
Cleveland, O.	98	3	17.8	35.6	17.9	99.3
Columbus, O.	30	3	17.8	23.6	18.1	98.5
Indianapolis, Ind.	62	5	29.2	22.9	28.5	102.3
Kansas City, Mo.	117	19	52.1	80.7	54.4	95.8
Los Angeles, Cal.	44	2	14.1	26.4	14.2	99.4
Louisville, Ky.	44	27	24.1	66.7	31.7	76.2
Memphis, Tenn.	15	21	19.0	40.1	27.4	69.4
Nashville, Tenn.	37	17	50.0	46.6	48.9	102.1
New Orleans, La.	67	40	26.8	44.8	31.5	85.3
New York, N. Y.	541	15	11.6	16.3	11.7	99.2
Philadelphia, Pa.	241	31	16.5	36.7	17.5	94.4
Pittsburgh, Pa.	142	7	28.0	27.3	27.8	100.5
Portland, Ore.	44	3	21.4	291.7	22.4	95.7
Richmond, Va.	15	13	18.6	27.8	21.9	85.1
St. Louis, Mo.	94	9	14.6	20.5	14.9	98.2
San Francisco, Cal.	62	3	14.9	183.0	15.5	96.3
Seattle, Wash.	32	2	13.6	87.0	14.2	95.9
Washington, D. C.	45	32	19.0	33.9	23.2	82.0

TABLE 32

White and colored typhoid fever death rate (1911)

City	Deaths from typhoid fever		Typhoid fever death rate per 100,000 population living			Per cent which white death rate was of total typhoid death rate
	White	Colored	White	Colored	Total	
Atlanta, Ga.	62	44	58.2	81.8	66.1	88
Baltimore, Md.	124	32	25.9	37.2	27.6	93
Birmingham, Ala.	35	27	42.4	50.3	45.5	93
Boston, Mass.	58	2	8.6	13.1	8.7	99
Chicago, Ill.	241	4	10.9	8.4	10.9	100
Cincinnati, O.	41	2	11.5	9.8	11.4	100
Cleveland, O.	—	—	—	—	—	—
Columbus, O.	25	1	7.6	14.4	13.9	54
Indianapolis, Ind.	55	7	25.3	31.2	25.8	98
Kansas City, Mo.	67	10	28.8	40.7	29.9	96
Los Angeles, Cal.	35	5	10.6	33.5	11.6	91
Louisville, Ky.	33	21	17.7	51.0	23.7	74
Memphis, Tenn.	43	44	53.9	82.6	65.4	82
Nashville, Tenn.	38	22	51.0	59.7	53.9	94
New Orleans, La.	59	48	23.2	52.6	31.0	75
New York, N. Y.	991	20	14.4	16.3	14.4	100
Philadelphia, Pa.	218	12	14.6	13.7	14.6	100
Pittsburgh, Pa.	133	6	25.8	22.8	25.6	100
Portland, Ore.	39	3	18.5	34.2	19.1	97
Richmond, Va.	16	7	19.5	14.8	17.8	109
St. Louis, Mo.	104	9	15.9	19.8	16.1	98
San Francisco, Cal.	55	10	13.5	58.0	15.3	88
Seattle, Wash.	—	—	—	—	—	—
Washington, D. C.	47	28	19.5	28.9	22.2	87

TABLE 33

White and colored typhoid fever death rate (1912)

CITY	DEATHS FROM TYPHOID FEVER		TYPHOID FEVER DEATH RATE PER 100,000 POPULATION LIVING			PER CENT WHICH WHITE DEATH RATE WAS OF TOTAL TYPHOID DEATH RATE
	White	Colored	White	Colored	Total	
Atlanta, Ga.	38	32	34.2	57.1	41.9	81
Baltimore, Md.	114	26	23.6	30.0	24.6	95
Birmingham, Ala.	33	23	36.3	38.8	37.3	97
Boston, Mass.	55	2	7.9	12.9	8.0	98
Chicago, Ill.	162	8	7.2	16.5	7.4	97
Cincinnati, O.	27	3	7.4	14.3	7.7	96
Cleveland, O.	—	—	—	—	—	—
Columbus, O.	34	4	18.9	29.3	19.6	96
Indianapolis, Ind.	40	4	17.9	17.3	17.8	100
Kansas City, Mo.	30	2	29.0	49.9	32.4	89
Los Angeles, Cal.	52	6	14.1	35.7	15.0	94
Louisville, Ky.	31	19	16.5	45.8	21.8	75
Memphis, Tenn.	34	47	41.3	85.4	58.9	70
Nashville, Tenn.	17	20	22.5	53.6	32.8	68
New Orleans, La.	30	19	11.6	20.5	14.0	83
New York, N. Y.	476	11	11.2	14.3	11.3	99
Philadelphia, Pa.	192	13	12.7	14.6	12.8	99
Pittsburgh, Pa.	70	2	13.4	7.5	13.1	102
Portland, Ore.	38	1	16.9	10.7	16.6	102
Richmond, Va.	16	6	19.2	12.5	16.7	114
St. Louis, Mo.	64	12	9.6	26.0	10.7	89
San Francisco, Cal.	54	5	13.0	28.5	13.6	95
Seattle, Wash.	—	—	—	—	—	—
Washington, D. C.	49	30	20.0	30.5	23.0	87

TABLE 34

White and colored typhoid fever death rate (1913)

City	Deaths from typhoid fever		Typhoid fever death rate per 100,000 population living			Per cent which white death rate was of total typhoid death rate
	White	Colored	White	Colored	Total	
Atlanta, Ga.	21	17	18.2	29.2	21.9	83
Baltimore, Md.	93	44	19.1	50.3	23.8	80
Birmingham, Ala.	27	30	28.2	48.1	36.0	78
Boston, Mass.	58	1	8.2	6.3	8.2	100
Chicago, Ill.	237	6	10.3	12.1	10.4	99
Cincinnati, O.	24	3	6.4	13.9	6.8	94
Cleveland, O.	—	—	—	—	—	—
Columbus, O.	35	3	18.9	21.3	19.1	98
Indianapolis, Ind.	52	10	22.6	42.1	24.4	92
Kansas City, Mo.	51	9	20.6	34.4	21.9	94
Los Angeles, Cal.	45	5	11.4	27.9	12.1	94
Louisville, Ky.	37	17	19.4	40.3	23.2	83
Memphis, Tenn.	28	20	33.3	35.6	34.2	97
Nashville, Tenn.	30	12	39.4	31.8	36.9	106
New Orleans, La.	38	22	14.5	23.4	16.9	85
New York, N. Y.	356	7	7.0	6.6	7.0	100
Philadelphia, Pa.	229	28	14.9	31.0	15.7	94
Pittsburgh, Pa.	101	8	19.0	29.6	19.5	97
Portland, Ore.	16	—	6.8	—	6.5	104
Richmond, Va.	18	9	21.3	18.4	20.3	104
St. Louis, Mo.	107	15	15.8	32.0	16.9	93
San Francisco, Cal.	66	5	15.6	28.0	16.1	96
Seattle, Wash.	—	—	—	—	—	—
Washington, D. C.	35	22	14.1	22.0	16.4	86

THE LATEST METHOD OF SEWAGE TREATMENT[1]

By Edward Bartow

Sewage treatment by aeration in the presence of sludge is the latest development in sewage disposal. Air has always played an important rôle in sewage disposal. The earliest application of air was the exposure of sewage on the ground or in shallow pools. The disposal of sewage by irrigation is, therefore, an aeration process. No more sewage can be added to land than can be thoroughly oxidized. The disposal of sewage by dilution in streams also depends on the amount of air present. The amount of sewage which can be purified by a stream is limited by the amount of dissolved oxygen present. The efficiency of the stream depends upon the amount of water or the amount of oxygen in solution or the possibility of reaeration.

Intermittent sand filtration where sewage is added intermittently to sand beds is an aeration process, for between the periods of flooding with sewage, air is allowed to enter the pores of the sand. The action of contact beds is of a similar nature. Coarser material is used and between the periods of flooding air enters the interstices and is the purifying agent. Sprinkling filters, the most practical process up to the time of the suggestion of activated sludge, depend upon aeration accomplished by spreading the sewage in a finely divided state into the air.

Preliminary to these aeration processes preparatory treatment is necessary. Preparatory treatment consists in using screens, grit chambers, settling tanks, digestion tanks or chemical precipitation. The preparatory treatment varies according to conditions. For example, three cities visited in Europe use different degrees of preparatory treatment prior to disposal by dilution. Munich uses no screening whatever, the water in the Yser being of sufficient quantity and sufficiently aerated to dispose of the sewage. Hamburg can dispose of its sewage in the lower Elbe using only coarse screening, but Dresden on the upper Elbe must pass its sewage through fine screens before emptying it into the river.

[1] A paper read at meeting of Iowa Section American Water Works Association, December 3, 1915.

Grit chambers and settling tanks remove suspended matter. The amount of purification is comparable with the amount of purification by screening.

Digestion tanks accomplish the partial destruction of the suspended solids and soluble organic matter by anaerobic bacteria.

The addition of chemicals assists sedimentation and retards digestion, giving an increased amount of sludge, but a much improved effluent. Neither the screening nor the sedimentation nor the digestion nor the chemical precipitation produce complete purification. Aeration processes must complete the purification.

The latest process, the aeration of sewage in the presence of sludge, has had a gradual development. Numerous experiments of blowing air into sewage have been made both in America and in Europe. Until recently none of the experiments were at all promising and the conclusion was that such means of purification was not practical. In this country, the first promising method was that used by Black and Phelps[2] in New York. They blew air through the sewage as it passed over a series of inclined wooden gratings. This sewage was in contact with the air for varying periods up to twenty-four hours. The results were promising enough to cause Black and Phelps to recommend the construction of a larger plant for Greater New York. That plant has not been constructed and the experimental tank has been adapted to experiments with activated sludge.

The next experiments are those reported by Clark, Gage and Adams[3] at the Massachusetts State Board of Health Experiment Station in Lawrence. Air blown through sewage reduced the organic constituents. The seeding of the sewage with green growths accelerated the action. Their best results were obtained when the tank contained slabs of slate covered with a brown growth of sewage matters. This treatment produced an effluent which could be filtered at several times the normal rate. It, however, simply prepared the sewage for addition to sand beds, and was not considered a final process.

Gilbert J. Fowler of the University of Manchester was in this country in November, 1912, in connection with the disposal of the sewage of Greater New York and visited the Massachusetts Experiment Station. Fowler and Mumford carried on experiments with a

[2] Report Concerning Location of Sewer Outlets and the Discharge of Sewage into New York Harbor (1911), 64–78.

[3] Annual Report Massachusetts State Board of Health (1913), 45, 288–304.

specific bacillus which they named M-7 which was collected from the waste water from a colliery. This bacillus with aeration has the power of separating iron as ferric hydroxide from iron bearing sewages, carrying down with it the suspended matter, and furnishing a nonputrescible effluent. Fowler suggested to Ardern and Lockett, who were in charge of the Manchester Sewage Disposal Works, that they try experiments in aerating sewage on lines somewhat similar to what he saw in Massachusetts. As a result the activated sludge process is being developed.

The first description of it was given by Ardern and Lockett,[4] April 3, 1914, at a meeting of the Manchester Section of the Society of Chemical Industry. In their first experiments Ardern and Lockett used bottles having a capacity of 5 pints, and drew the air through the sewage by means of an ordinary filter pump. Air was drawn through the sewage until it was completely nitrified, requiring about five weeks. The supernatant liquid was drawn off and additional sewage added. This method of treatment was repeated a number of times with the retention each time of the deposited solids. As the amount of deposited matter increased the time required for each succeeding oxidation gradually diminished. Finally a well oxidized effluent, equal to that from efficient bacterial filters, was obtained in from 6 to 9 hours.

In their second series of experiments, reported to the Manchester Section of the Society of Chemical Industry,[5] November 6, 1914, they used barrels of 50 gallons capacity and added the air through porous tile. They have tried treatment with a continuous flow of sewage without conclusive results. In later experiments they used tanks of 20,000 gallons capacity. Their results were very satisfactory and led to additional work in England, especially at Salford where Duckworth[6] and Melling[7] adapted scrubbing filters to the use of the activated sludge process with great success. In August, 1914, the author had the privilege of meeting Professor Fowler and of seeing the work which had been done under his direction. On returning to this country, consulting with Fowler, experiments[8]

[4] *J. Soc. Chem. Ind.*, 33, 523–539.

[5] *J. Soc. Chem. Ind.*, 33, 1122–1124 (1914).

[6] *Surveyor*, 46, 681–682 (1914).

[7] *J. Soc. Chem. Ind.*, 33, 1124–1130.

[8] *Jour. Ind. Eng. Chem.*, 7, 318 (1915). *Eng. News*, 73, 647–648 (1915); *Eng. Record*, 71, 421–422 (1915); *Eng. Contrg.*, 43, 310–311 (1915).

were begun with F. W. Mohlman at the University of Illinois on November 2, 1914, using bottles of 3 gallons capacity. On January 4, 1915, a tank 9 inches square and 4½ feet deep was put in operation. In the bottom of this tank was placed a porous plate made of material known as "Filtros," furnished by the General Filtration Company, Rochester, New York. The plates are made of a very pure and carefully graded quartz, fused together with powdered glass.

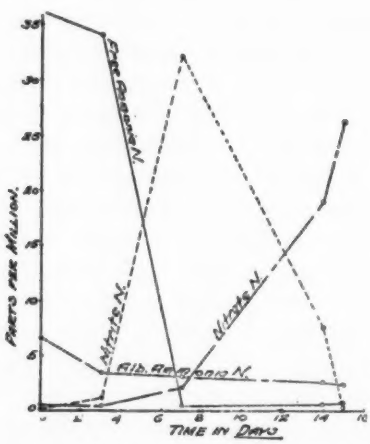


Fig. 1. Nitrification of Sewage. No Activated Sludge Present Uniform Distribution of Air Through Porous Plate

The results of our first experiments were similar to those of Ardern and Lockett. Sewage placed in the bottles or in the little tank was submitted to a current of air for a sufficient period to oxidize it completely. The oxidization is best measured by the content of ammonia, nitrate, and nitrite nitrogen. Oxidation has been carried to completion five different times with practically the same results. The time required for oxidation differed, but the courses of the reaction were similar. As an example in one of these experiments, at the beginning, 35 parts per million of ammonia nitrogen were present (see fig. 1). The ammonia nitrogen remained practically constant for about 4 days and then quite rapidly decreased so that at the end of about 7 days it was gone. There were no nitrates nor nitrites present in the raw sewage. The nitrites increased as the ammonia decreased. Then for a few days the nitrites

remained constant and then decreased, the nitrates which were zero at the start increasing as the nitrites decreased. At the end of fifteen days, nitrification was complete, the nitrite nitrogen had practically disappeared and the nitrate nitrogen had increased to about 25 parts per million. When the oxidation was complete the supernatant liquid was replaced by fresh sewage, the sludge being left. This process was repeated. With each change less time was required for oxidation, as for example, 15 days for the first, 4 days for the second, and 2 days for the third, and so on, until with the thirty-first treatment oxidation was complete in 5 hours.

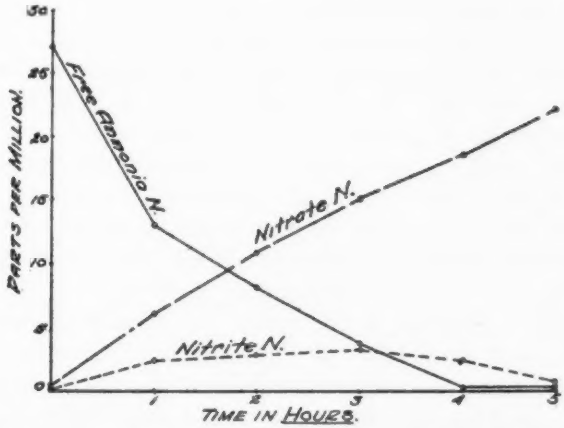


FIG. 2. NITRIFICATION OF SEWAGE. ACTIVATED SLUDGE PRESENT
1 SLUDGE: 5 SEWAGE

With accumulation of sludge as the process is repeated the reaction follows a different course, for example (see fig. 2), using a sewage with 27 parts per million of ammonia nitrogen, the ammonia decreased and is practically eliminated in 5 hours. The nitrite nitrogen never increased to any extent, the nitrate nitrogen begins to increase almost at the start, increasing as the ammonia nitrogen decreases, and reaches its maximum when the ammonia nitrogen has disappeared. It is not necessary to obtain complete nitrification to obtain a clear or stable effluent. More information must be obtained before the amount of nitrification required can be known.

The process is undoubtedly bacteriological. The sludge is very

rich in bacteria but the number in the effluent is comparatively small.

The fresh sludge is odorless. It will putrefy if left with a large amount of water. After filter pressing it is stable. The dried sludge has an odor similar to that of fertilizers.

As in other sewage disposal processes, the ultimate disposal of the sludge is of great importance. Near the seaboard it is possible to carry it out to sea, but in the interior, the problem of sludge disposal is often very serious.

In the experimental plant at the University of Illinois in Urbana, they have tried to study all phases of the process,[9] and have paid especial attention to the sludge.

The amounts of sludge formed and its chemical composition evidently vary with the concentration of the sewage, and with temperature conditions. The sewage treated in the experimental plant during rainy weather contains large amounts of diluting water, which reduces the amount of sludge per unit of water. The diluting water carries considerable dirt from the streets which reduces the nitrogen content of the sludge obtained. Also during warm weather, bacteriological action is more rapid, and apparently, the amount of sludge is considerably reduced.

The sludge obtained in the process is flocculent, resembling a freshly formed precipitate of ferrous-ferric hydroxide. It separates easily from the clarified water, and after one hour's settling contains about 98 per cent of water. On further standing, about one-half of this water can be removed. The remaining material can be dried by filter pressing or by drying on beds of sand and evaporating over steam baths.

The disposal of the sludge can be most easily accomplished if it has manurial value. That activated sludge has manurial value is shown by its chemical composition, by its reaction with various soils, and by its effect on the growth of plants. Specimens of sludge obtained at the experimental plant have varied in nitrogen content from 3.5 to 6.4 per cent. The lower values were obtained during periods of high water. The tests of the fertilizer value have been made on the richer specimens which were first obtained.

Through the courtesy of Mr. Paul Rudnick, chief chemist, Armour and Company, Chicago, the availability, according to alkaline per-

[9] *J. Ind. and Eng. Chem.*, 7, 318–320.

manganate method as used by the New England states was shown to be below 50 per cent (44.7 per cent), and the sludge would be classed as an inferior ammoniate, but the availability according to the neutral permanganate method which has been adopted by the southeastern states was shown to be about 85 per cent (89.0 per cent), and would therefore be classed as satisfactory.

Tests have been made by Prof. C. B. Lipman, according to a method described by Lipman and Burgess,[10] in which a fertilizer and a soil are incubated for a month. The amount of nitrogen changed into nitrate is then determined. This amount is an index of the availability of the nitrogen with respect to the soil used. The results obtained were reported by Professor Lipman as follows:

The activated sludge used contained 6.2 per cent total nitrogen and no nitrate. The hundred grams of soil in every case contained nitrate as follows:

	milligrams nitrogen
Anaheim soil	1.0
Davis soil	0.3
Oakley soil	0.1

The amounts of nitrate produced in one month's incubation from the soil's own nitrogen and from the nitrogen of the sludge mixed with the soil in the ratio of one part of sludge per hundred of soil as is follows:

	milligrams nitr te produced
Anaheim, without sludge	6.0
Anaheim, with sludge	10.0
Davis soil, without sludge	4.2
Davis soil, with sludge	14.0
Oakley soil, without sludge	2.2
Oakley soil, with sludge	4.0

The Davis soil is the best nitrifying soil of the three, especially for high grade organic material. Anaheim is next, and the Oakley by far the poorest. Indeed, the last named does not nitrify in a period of a month in the incubator the nitrogen of dried blood at all.

These figures indicate that the general tendency is to make available the nitrogen of sludge in type soils at about the same rate that nitrogen is transformed into nitrate in such organic nitrogenous fertilizers as fish guano. While it seems to hold a medium position, it nevertheless resembles very much more closely in its general chracteristics, so far as available nitrogen is concerned, the so called high grade organic nitrogenous fertilizers, dried blood and high grade tankage, etc., rather than the low grade nitrogenous fertilizers, steamed bone meal, cotton seed meal, garbage tankage, etc.

[10] Univ. of Calif., Bul. 351 (1915).

Although the chemical tests and the nitrification tests with soils indicate that the activated sludge has a high fertilizer value, the final test must be its effect on plant growth. Pot cultures, using wheat, were started in March, 1915, by W. D. Hatfield[11] under the general direction of Prof. C. G. Hopkins and with the assistance of Mr. J. C. Anderson. The contents of the pots in which the wheat was planted were as follows:

POT NUMBER	1	2	3	4
	grams	*grams*	*grams*	*grams*
(1) White sand	19,820	19,820	19,820	19,820
(2) Dolomite	60	60	60	60
(3) Bone meal	6	6	6	6
(4) Potassium sulphate	3	3	3	3
(5) Activated sludge	0	0	20	0
(6) Extracted sludge	0	0	0	20
(7) Dried blood	0	8.61	0	0

Each pot contained an equivalent of 5 tons per acre of dolomite, $\frac{1}{2}$ ton per acre of bone meal, and 500 pounds per acre of potassium sulphate.

Pot 1, the check pot, contained only 60 milligrams of nitrogen which were added in the bone meal. This small amount was without significance since the same amount was added to the other pots. Pot 2 contained an equivalent of 120 pounds of nitrogen per acre added in the form of dried blood. Pots 3 and 4 contained an equivalent of 120 pounds of nitrogen in the form of dried activated sludge, one ton of sludge per acre. Following is an analysis of the sludge used:

	per cent
Total nitrogen	6.3
Phosphorus (P_2O5)	2.69
Ether soluble (3 hours extraction)	4.00
Ether soluble (16 hours extraction)	11.8

Thirty wheat seeds were planted, two seeds in each of fifteen holes, in each pot. At the end of eighteen days the plants were thinned to fifteen of the best in each pot in most cases leaving one plant to each hole. In twenty days from date of planting there was a marked showing in favor of the plants in pots 3 and 4. In twenty-three days the plants in pots 3 and 4 (see fig. 3), were growing far

[11] *Ind. Eng. Chem.*, 7, 318–320.

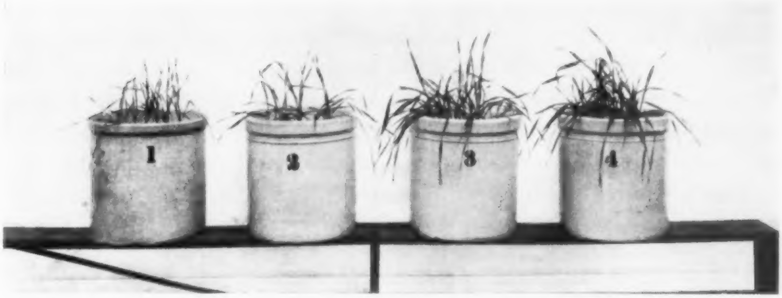


FIG. 3. POT CULTURES, WHEAT TWENTY-THREE DAYS AFTER PLANTING

Each pot contains pure white sand to which the same amount of plant foods except nitrogen have been added. No. 3 contains 20 grams dried activated sludge. No. 4 contains the same amount extracted with ligroin. No. 2 contains an equivalent of nitrogen from dried blood and No. 1 contains no nitrogen.

FIG. 4. POT CULTURES, WHEAT SIXTY-THREE DAYS AFTER PLANTING

Each pot contains pure white sand to which the same amount of plant food except nitrogen have been added. No. 3 contains 20 grams dried activated sludge. No. 4 contains the same amount extracted with ligroin. No. 2 contains an equivalent of nitrogen from dried blood and No. 1 contains no nitrogen.

ahead of 1 and 2. After nine weeks the difference was very marked (see fig. 4).

In fourteen weeks the plants in pots 3 and 4 began to head and in fifteen weeks there were about twenty good heads in each. The plants in pot 1 were very weak, while those in pot 2 were just beginning to develop heads.

When it was first noticed that the plants fertilized with sludge were growing much better than those fertilized with dried blood, in order to confirm the results a second series of pot cultures was started. In this series the sludge was compared with dried blood, nitrate of soda, ammonium sulphate and gluten meal. This series contained fourteen pots, two check pots, six containing nitrogen equivalent equal to an application of 20 grams of sludge, and six containing nitrogen equivalent to 30 grams of sludge. The plants in this series grew faster than those in the first because of better weather. They showed exactly the same characteristics that the plants in the other series showed. The plants fertilized with sludge were the best. The results confirmed the results obtained in the first series. At the end of five weeks striking differences were noticeable (see fig. 5). The pots containing the equivalent of 30 grams of sludge gave no better results than those with an equivalent of 20 grams.

When the wheat matured it was carefully harvested and calculations made to determine the yield per acre. The results are shown in a table.

Amounts of wheat and straw obtained in the first series

POT NUMBER	1	2	3	4
Number of heads	14.0	15.0	22.0	23.0
Number of seeds	85.0	189.0	491.0	518.0
Weight of seeds	2.38 g.	5.29 g.	13.748 g.	14.504 g.
Bushels per acre (calculated)	6.20	13.6	35.9	37.7
Average length of stalk	19.40 in.	23.0 in.	35.40 in.	36.1 in.
Weight of straw	2.25 g.	8.25 g.	26.75 g.	26.21 g.
Tons per acre (calculated)	0.18	0.68	2.23	2.18

The control series gave results corresponding to those of the first series.

The surprisingly rapid growth of the wheat fertilized by the sludge must be due for the most part to nitrogen present in a very

available form. It may be due in part to the phosphorus (2.69 per cent) which is present in the sludge. At the time of making the pot cultures the phosphorus was not considered since it was present in such a small quantity. The growth may be due in part to the organic matter present in the sludge, since the sand used contains no organic matter.

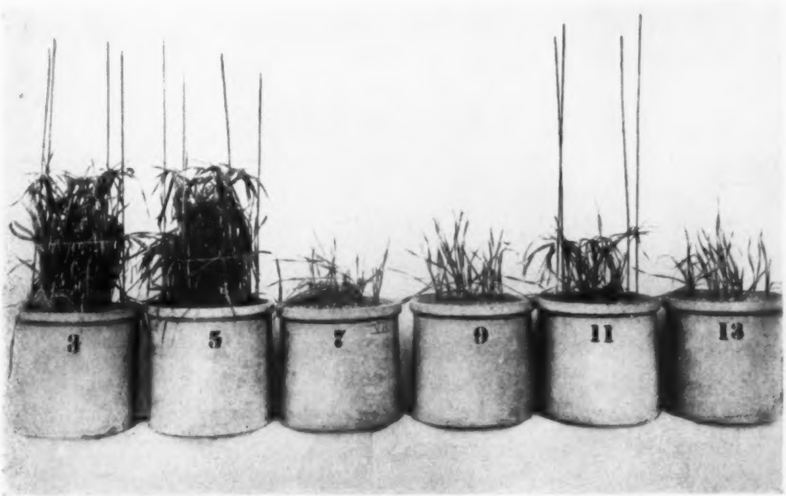


FIG. 5. POT CULTURES, WHEAT SERIES 2, THIRTY-FIVE DAYS AFTER PLANTING

Each pot contains pure white sand to which the same amount of plant foods except nitrogen have been added. No. 3 contains 20 grams dried activated sludge. No. 5 contains 20 grams of dried activated sludge from which other soluble matter has been removed. No. 7 contains the nitrogen equivalent from sodium nitrate. No. 9 contains the nitrogen equivalent from ammonium sulphate. No. 11 contains the nitrogen equivalent from gluten meal. No. 13 contains the nitrogen equivalent from dried blood.

The sludge causes such a rapid growth of wheat, that it should be valuable to truck gardeners, to rush the spring crops. To test its value to the market gardener, three plots each 2 feet by 3 feet were laid out in a field. One plot was not fertilized, one was fertilized with an equivalent of 126 pounds of nitrogen, 1 ton of sludge per acre, and the third with an equivalent of extracted sludge. On April 24, 1915, two rows of radishes and lettuce were planted in each of the three plots. The plants in the plot where the extracted sludge

was used, came up first, a little ahead of those in the plot where the unextracted sludge was used. At the end of four weeks the plants were thinned. The roots of the radishes from the treated plots were already red and quite rounded near the tops while those from the untreated plots had not yet started to swell and had not become red.

On June 1, 38 days after planting, the six best plants of lettuce and radishes were taken from each plot (see fig. 4). The differences in size were very marked.

Comparison of the lettuce and radishes from unfertilized and fertilized plots

PLOT	TREATMENT	WEIGHT OF LETTUCE	WEIGHT OF RADISHES
		grams	*grams*
1	None	4.5	23.4
2	Sludge	6.3	63.0
3	Extracted sludge	6.8	68.0

The increase in weight, due to the sludge, is 40 per cent in the lettuce, and nearly 300 per cent in the radishes. The radishes from the sludge pots when cut open and eaten were found to be very crisp and solid, and to have a good flavor.

These pot cultures and gardening experiments show that the nitrogen in "activated sludge" is in a very available form and that activated sludge is valuable as a fertilizer.

The process is attracting a great deal of attention in America, and a very good statement concerning the work being done is given in *Engineering News*, July 15.[12] Mr. M. N. Baker has given an editorial review of the subject. The most extensive work is being done at Milwaukee. An article by Mr. T. Chalkley Hatton[13] gives a more complete account of the Milwaukee experiments. Two tanks of 1 x 5 x 10 feet deep and one tank $10\frac{1}{2}$ x 32 x 10 feet deep have been operated on the fill and draw plan and one tank $10\frac{1}{2}$ x 32 x 10 feet deep has been operated on the continuous plan. The Milwaukee Sewerage Commission has awarded contracts for the construction of a plant to treat 2,000,000 gallons of sewage per day by continuous flow. At Baltimore, they have been working on a small scale but have also adapted two of the new Imhoff

[12] *Eng. News*, 74, 164–171 (1915).
[13] *Eng. News*, 74, 134–137 (1915).

tanks for use by this process, and it is expected that in a short time they will be treating sewage with activated sludge on a large scale. At Washington, the Hygienic Laboratory of the Public Health Service is experimenting on a small scale and is coöperating with the Department at Baltimore in their experiments. At Cleveland,

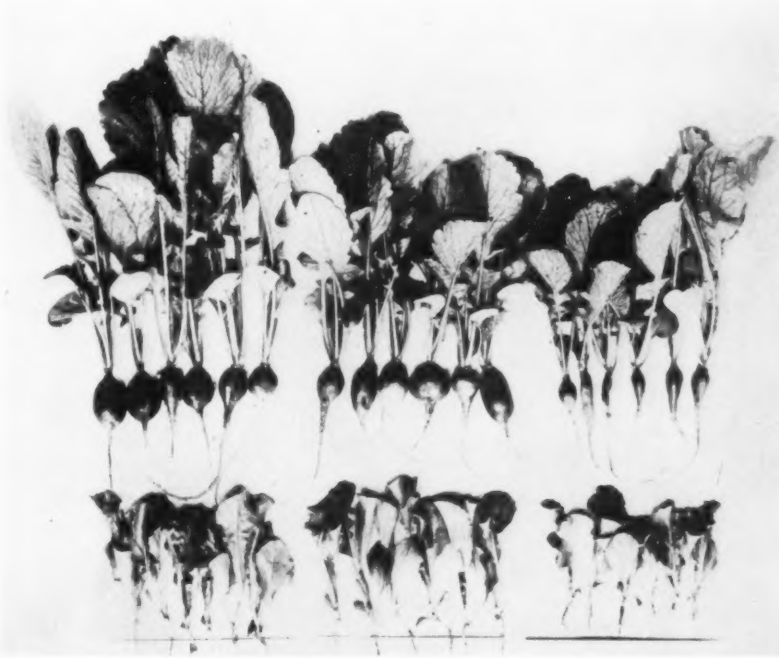


FIG. 6. GARDENING EXPERIMENTS THIRTY-EIGHT DAYS AFTER PLANTING

Radishes. From left to right, six radishes fertilized with extracted sludge, six radishes fertilized with sludge, six radishes unfertilized. Lettuce. Six heads fertilized with extracted sludge, six heads fertilized with sludge, six heads unfertilized.

experiments are being carried on in the sewage experiment station. They have adapted tanks 5 x 10 and 5 feet deep which they used in their sewage experiments to the process, and while it has barely begun they are getting promising results. Experiments are to be carried out on a larger scale. At Regina, Saskatchewan, experiments on a considerable scale have been carried out and their

results are reported by R. O. Wynne-Roberts.[14] At Houston, Texas, they are planning to use the process in a plant to ultimately treat the sewage from 160,000 people. They do not expect to obtain complete nitrification as they do not believe that a completely purified effluent is necessary. In Chicago the Sanitary District of Chicago is using tanks about two feet in diameter and eight or ten feet high with quite satisfactory results, using the waste from the stock yards, one of the most difficult wastes to treat. A

FIG. 7. TANKS FOR PURIFICATION OF SEWAGE BY AERATION IN PRESENCE OF ACTIVATED SLUDGE

larger plant is being built. At the University of Illinois four re inforced concrete tanks have been completed and put in operation. These tanks, operating on the fill and draw system, are designed for studying in a comparative manner the amount of air required, the best method for distributing the air, the time required for purification, and the quantity and quality of activated sludge formed.

The tanks are located in the basement of the University power plant (see fig. 7). The room is not affected by heat from the boilers

[14] *Canadian Engineer*, 29, 112, 113 (1915).

and conditions are similar to those which would be obtained by housing a plant.

It was very easy to tap the city of Champaign main sewer which passes underneath the coal hopper (see fig. 8) of the power plant. The sewage is pumped to the tanks by a 2 h.p. centrifugal pump run by a direct connected motor.

Each tank is 3 feet 2 inches square having an area of 10 square feet. Each tank is 8 feet 5 inches in depth above 1½ inch Filtros plates which are used for diffusing the air. In two tanks there are 9 plates, each 12 inches square, covering the entire floor. In the third tank there are 3 plates, covering one-third the area of the floor, forming the bottom of a central trough. The remainder of the bottom slopes to the plates at an angle of 45 degrees. In the fourth tank is a single plate in the center covering one-ninth the area with the bottom sloping to it at an angle of 45 degrees from all sides. Below the plates is an air space 4 inches deep. A pet cock is provided to relieve the air pressure when draining the tank and to prevent air bubbles from rising and stirring up the sludge. The air obtained from the University compressed air plant at a pressure of 80 pounds is reduced by a pressure reducing valve to 8 pounds and is further regulated by a hand operated valve before passing through meters on each tank. The pressure under which it enters the tank is sufficient only to overcome the pressure of the sewage and friction of the plates equivalent to about 8 inches of mercury or a little less than 4 pounds per square inch.

Two outlets for the effluent are respectively 2 feet 6 inches and 5 feet 7 inches above the porous plates. A tank can be filled in 6 minutes and drained to the lower outlet in eight minutes.

Experience has shown that a lower outlet connected to a floating outlet would be preferable. A fixed outlet is objectionable because sludge is at times drawn out with the effluent. In order to prevent this loss, a floating outlet made of two-inch pipe connected together with loose joints, has been placed in tank C. With this arrangement no sludge has been lost and accurate data are expected concerning the amount of sludge formed from the sewage.

The amount of sludge must be determined by weight on the dry basis for it has been noted that its volume and rate of settling vary with the amount of air applied. If an unusually large amount of air has been applied, the sludge will settle more slowly and will occupy a much greater volume, even after prolonged settlement, than it does when less air has been applied.

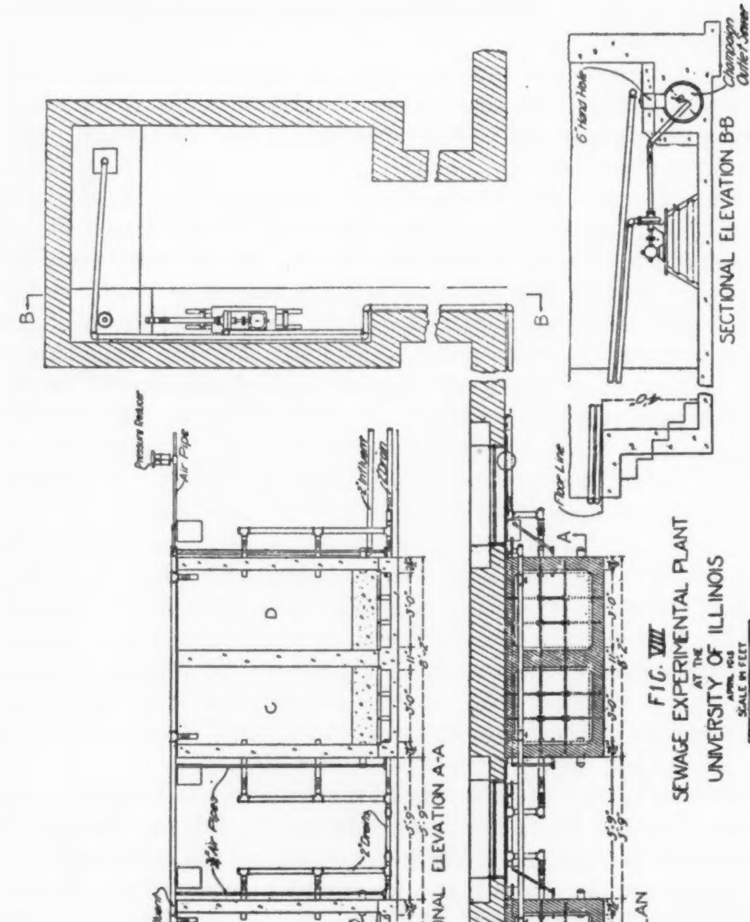


FIG. VIII
SEWAGE EXPERIMENTAL PLANT
AT THE
UNIVERSITY OF ILLINOIS
SCALE IN FEET

BUILDING UP OF SLUDGE

If in accordance with previous practice, activated sludge is built up by complete nitrification of each portion of sewage added, it would require several weeks to put a plant in operation. In order to obtain sludge more quickly the English investigators have used sludge from sprinkling filters. At Milwaukee, Imhoff tank sludge has been aerated until it is aerobic and similar to activated sludge. Such a source of sludge would not be available in many places, especially at newly installed plants. The university plant has attempted to shorten the period of sludge formation.

Tanks A and B were filled with the same kind of sewage on May 5, 1915. The sewage in tank A was aerated continuously. The sewage in tank B was aerated 23 hours, allowed to settle, the supernatant liquid withdrawn and the tank was refilled with fresh sewage. This cycle was repeated daily. Determinations of the amount of sludge and of the degree of purification were made daily.

At the end of 10 days, after one hour's settling in Imhoff cones, 1.0 per cent of the volume in tank A consisted of sludge while about 10 per cent of the volume in tank B was sludge. The effluents from tank A which had been aerated 10 days and from tank B which had been aerated one day were equally stable while that from tank B was clearer.

Later experiments showed that satisfactory activated sludge could be built upon a 6 hour cycle. A considerable degree of purification is obtained from the beginning of the operation, and the time for building up adequate sludge for the process is cut down very decidedly.

DIFFUSION AREA REQUIRED

The bottom of tank C contains three square feet of Filtros plates as described above. The bottom of tank D contains one square foot. These tanks were put in operation July 6 and the sewage changed every 6 hours. There was a noticeable difference in the action in these tanks. Tank C gave some stable effluents after 5 days; tank D did not give stable effluents in 18 days. The sludge from C was of good appearance, while that from D was not as flocculent and at times had a septic odor. During the comparative experiment an average of 450 cubic feet of air per 400 gallons of sewage was used with tank C, and 360 cubic feet per 400 gallons of

sewage with tank D. The amount of air given tank D was always sufficient to keep the sludge mixed with the sewage. In fact, the sewage in tank D was agitated much more violently than that in tank C. It was concluded that 1 square foot of filtros plate per 10 square feet of floor area is hardly sufficient. Of the four tanks tank C with 3 square feet of filtros plate per 10 square feet of floor area, has given the best results.

It was noted that it is quite essential that the plates be as nearly as possible at the same level. A variation of ¼ inch in level will cause uneven air distribution. The distribution seems to become more uniform the longer the plates are used.

QUALITY OF EFFLUENTS

The quality of the effluents has usually depended more on the strength of the raw sewage than upon any other variable. The tanks, when operating on a 6 hour cycle, were filled at 9 a.m., 3 p.m., 9 p.m., and 3 a.m. The strength of the raw sewage, estimated by the ammonia nitrogen, is for the 9 a.m. sewage between 20 and 35 parts per million, for the 3 a.m. sewage between 3 and 12 parts per million. Nearly all of the 3 a.m. sewages have given stable effluents, but the strong morning sewages have quite frequently given putrescible effluents. Unless the sludge is in good condition, and well nitrified, a strong sewage cannot always be purified in 4½ hours even by increasing the air to 800 cubic feet per 400 gallons. In the normal working of the plant the sludge will usually regain its "activity" if 800 cubic feet of air is applied for several periods after the strong sewage has been added.

At times, however, with a succession of strong sewages, it is necessary to increase the time of aeration in order to obtain good effluents. Ardern and Lockett[15] noted in their first paper that if the aeration was stopped before the sewage was well nitrified, the activity of the sludge would be inhibited. When strong sewages are to be treated a definite cycle of operation probably cannot be established without provision for longer aeration of the sewage or separate aeration of the sludge. In order to keep the sludge in its most active state, complete nitrification of each sewage is necessary. Effluents are usually stable if 50 per cent of the free ammonia is removed, and 2 to 3 parts per million of nitrogen as nitrates is

[15] *Jour. Soc. Chem. Ind.* 33, 623–639.

present. A completely nitrified effluent is neither necessary nor economical.

The greatest efficiency in air consumption will be obtained when enough air is used to make the sewage nonputrescible and to keep the sludge activated. The operation of the plant during six months has suggested the advisability of studying more carefully such other features of the process as the amount of sludge formed, the building up of nitrogen in the sludge and the composition of the effluent gases.

EXPERIENCE WITH A CARD CONSUMERS' LEDGER

By W. E. Haseltine

On the first day of October, 1906, the Ripon Light and Water Company was fortunate enough to have its office burn to the ground, carrying with it not only all of the gas, electric and water bills, made out and ready for distribution, but also all of the consumers' records, meter readings, maps and data.

Needless to say, this was not at the time looked upon as an unmixed blessing—in fact it was considered something to be more or less put out about, and it was some time after the smoke had cleared away before it was realized what an opportunity it created. The slate was wiped clean—no consumers' ledgers, no bill forms, no meter reading records, nothing which must be conformed to in starting a new set of books. When this was clearly realized, the decision was, "Now let's get right down to brass tacks, forget everything we have ever used or seen used, and see if we can't get out something that will simplify our work, and give us all the information we want in easily get-at-able form."

Three methods of keeping consumers' accounts seemed open:

First. Regular bound books.

Second. Loose leaf books.

Third. Card records.

Consideration of the advantages and disadvantages of these three methods seemed to point to the latter as having the most to commend it, and after nearly ten years actual use, there has been no reason to change that opinion.

The first thing done was to adopt a standard color for all cards, bills and forms for each department: white for water, blue for electricity, salmon for gas, and yellow for merchandise and repairs.

Next the size of cards was experimented with.

The consumers' ledger formerly used was about 14 x 18 inches, but it was found, after making up several forms, that a large amount of matter could be gotten into a small space, by cutting down margins, narrowing up columns, etc., and the experiments finally ended

with a card 5 x 8 inches, with ample space for all necessary statistics on one side, and room for eight years quarterly collections, or four years monthly collections on the other. This is now the standard size for consumers' ledger cards in all departments.

A similar set of experiments resulted in reducing all other records, meter reading cards, meter records, work slips, orders, sales slips, merchandise ledger, delinquent ledger, etc., to a standard of 3 x 5 inches.

The previous practice had been to make the forms any size that happened to seem convenient, but it was found that all could be made one standard just as well, by giving a little thought to their arrangement, and this resulted in having to use only two sizes of filing drawers, the interchangeability of which is sometimes a great convenience.

Having the cards decided upon, two vault omnibuses were built to contain these records, one of which was for the bookeeper's use and one for the manager's. These are now safely tucked away in a fireproof vault every night so that experience of the loss of records by fire will not have to be repeated.

These omnibuses contain all of the active records of the company, and the head bookkeeper can, without moving from his chair, reach every consumer record in all departments. By distributing the various drawers, or portions thereof, he can assign the work as desired.

Now as to the actual records:

For a consumers' ledger a uniform card is used whether the consumer be flat rate or metered. Figure 1-A and figure 1-B show both sides of a metered consumers' card, and figure 2-A and figure 2-B both sides of a flat rate consumers' card.

Referring to figure 1-A, it will be noted that this card is arranged for eight years, using quarterly collections. The card number 983 refers to the premises, and the names written in to the occupants, the last name being the latest occupant. Figure 1-B the reverse side of the same card, shows the location of the premises, the date service was installed, the location of the stop box, an arbitrary house number (this is used in connection with the gas and electric records) the fixtures which the premises contains, all changes in same, when and by whom made, the various occupants of the premises, the dates of occupation and vacation, and the dates of turning off and on the water.

No. 983 | Name D. C. Reynolds | Name | Name
Div. Domestic | Name C. J. Hill | Name | Name
Class Residence | Name | Name | Name

Date	Meter read	Cubic feet	Gallons	Amount	Meter Rent	Total	Date Pd
3/20 1915 April	9390	639	4793	1.19	.56	1.75	4-7
6/22 July	10622	1232	9240	2.31		2.31	7-8
9/22 Oct.	11631	1009	7568	1.89		1.89	10-8
12/22 Jan.	13290	1659	12443	3.11		3.11	1-8
Total		4539	34044	8.50	.56	9.06	
1916 April							
July							
Oct.							
Jan.							
Total							
1917 April							
July							
Oct.							
Jan.							
Total							
1918 April							
July							
Oct.							
Jan.							
Total							

Date	Meter read	Cubic feet	Gallons	Amount	Meter Rent	Total	Date Pd
1919 April							
July							
Oct.							
Jan.							
Total							
1920 April							
July							
Oct.							
Jan.							
Total							
1921 April							
July							
Oct.							
Jan.							
Total							
1922 April							
July							
Oct.							
Jan.							
Total							

FIG 1-A

No. 983

WATER SERVICE.

Class Residence

No. 322, Thorne St., N side, bet. Watson St. and Newbury St.

Installed June 17, 1907 House 857

Stop Box 6 feet 6 inches (~~inside~~) (outside) Property line and 37 feet and 9 inches E of E line of Watson St.

Date / Fixtures.	City Water Rate	Soft Water Rate	Fixtures Added.	Rate	Plumber	Date	Occupant	Occu'd	Vac'ed	Off or On	Date
10 Rooms							D. C. Reynolds	6/17/07	9/1/12	OFF	9/1/12
1 Sinks							C. J. Hill	1/1/13		ON	1/1/13
1 Baths											
1 Lavatories											
1 Water Closets											
Urinals											
Sill Cocks											
Hydrants											
1 Water Lift											
Horses											
Cows											

FIG 1-B

No. 982 Name A. B. Carter Name Name

Div. Domestic Name W. B. Foster Name Name

Class Residence Name L. A. Burgess Name Name

Date	Meter read	Cubic feet	Gallons	Amount	Meter Rent	Total	Date Pd
1915 April	14.50					3.62	4-9
July						3.63	7-9
Oct.						3.62	10-11
Jan.						3.63	1-10
Total						14.50	
1916 April							
July							
Oct.							
Jan.							
Total							
1917 April							
July							
Oct.							
Jan.							
Total							
1918 April							
July							
Oct.							
Jan.							
Total							

Date	Meter read	Cubic feet	Gallons	Amount	Meter Rent	Total	Date Pd
1919 April							
July							
Oct.							
Jan.							
Total							
1920 April							
July							
Oct.							
Jan.							
Total							
1921 April							
July							
Oct.							
Jan.							
Total							
1922 April							
July							
Oct.							
Jan.							
Total							

FIG 2-A

No. 982

WATER SERVICE

Class Residence

No. 576 Ransom St., West side, bet. Seward St. and Thorne St.

Installed Apr 26,1912 House 1756

Stop Box 7 feet 2 inches [illegible] (outside) Property line and 72 feet and 4 inches N of N line of Thorne St.

Date	Fixtures	City Water Rate		Soft Water Rate	Fixtures Added	Rate	Plumber	Date	Occupant	Occu'd	Vac'd	Off or On	Date
5	Rooms	4	50						A. B. Carter	4/6.12	10/1.14	OFF	10/1.14
1	Sinks								W. B. Foster	1/1.15	6/1.15		
1	Baths			X					L. A. Burgess	6/1.15			
1	Lavatories			X									
2	Water Closets	5	50										
	Urinals												
	Sill Cocks												
	Hydrants												
1	Water Lift	4	50										
	Horses												
	Cows												
		14	50										

FIG 2-B

The above explanation will also cover the flat rate card figure 1-A and figure 1-B, the annual flat rate being carried out in the meter reading column. If this premises goes upon a meter it is not necessary to change the card, but simply to enter up the meter reading in the proper column, and file the card with the metered consumers.

In the card drawers there are three chief divisions: Unpaid, Paid, and Turned Off. These are subdivided into classes such as Domestic Flat Rate, Domestic Metered Rate, Commercial Flat Rate, Commercial Metered Rate, etc.

At the beginning of a quarter all active cards, with amounts payable carried out, are placed in the "Unpaid" section. As these are paid, and dates of payment entered upon the cards, they are transferred into the "Paid" section. Therefore at the end of the month or payment period the "Unpaid" section will contain in compact form only those accounts remaining unsettled, which are disposed of by turning off or enforcing collection in the regular way.

No back or unpaid accounts are carried upon these cards, all delinquent accounts being transferred, at the end of the month or payment period into a little 3 x 5 inch "Delinquent Ledger" whether these delinquent accounts are for water, gas or electricity. In this way the consumers' ledgers are kept clear, and all delinquent accounts are bunched where they can be easily referred to and handled.

When an unpaid account is carried into the delinquent ledger the date of this transfer is made in the "Date Paid" column of the consumer's ledger card, but in red ink. This shows at a glance how often and when a consumer has been delinquent.

All meter readings, whether of water, gas or electric meters, are taken on uniform cards shown in figure 3. These cards are 3″ x 5″.

With direct reading meters the readings are entered on the card by the reader, but in all other cases he simply marks the position of the hands, and the readings are carried out in the office.

These meter reading cards are normally kept in order of service number in the bookkeeper's file. At meter reading time the meter reader arranges all the cards on his route in the order of reading, takes out a pack of these, and as he reads the meters, places the read cards in his pocket. If he cannot read a meter, he places this card on the bottom of the pack. At the end of the day he turns into the office those which have been read, retaining only those still unread.

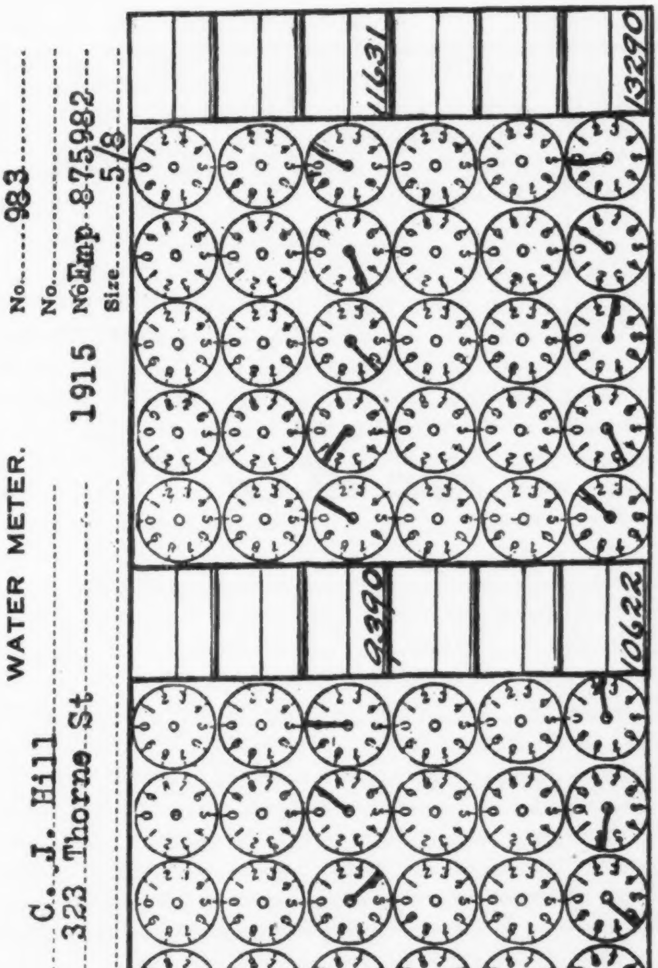


FIG. 3. THE ORIGINAL CARD IS ONLY 3" x 5"—A BETTER IMPRESSION WOULD BE GIVEN IF THE CUT WERE NOT MORE THAN ACTUAL SIZE, PARTICULARLY AS THE COMPACTNESS OF THESE CARDS IS REFERRED TO IN THE TEXT

WATER METER. No. 875982

Make Empire Size 5/8 Type AAX

Date	Put in	Reading		Tested	Remarks
Feb 3 1907	Stock	0	00		
June 17 '07	D. C. Reynolds	0	00		
Sept 1 1912	Stock	117	85	10/22 '12	O.K.
Jan 1 1913	C. J. Hill	0	00		

FIG 4 A

TEST RECORD.

Date	Opening	Reg.	Lbs EXX	% F	% S
10/22 '12	1/32	1	63.3		1.4
	1/16	1	63.0		1.0
	1/8	1	62.8		.7
	1/2	1	62.7		.5
	INDEX RE-SET TO 000				

FIG 4 B

These cards have the advantage over meter books of being much smaller, easier to handle and less liable to tear. Further the system is more flexible, as the office can be entering up part of a route while the meter reader is finishing it. These cards, as fast as entered, are returned to the file in order of number, completing the cycle.

Meter records are kept on the 3 x 5 inch cards shown front and back in figure 4-A and figure 4-B. These require no explanation.

The vault files are arranged the same as the omnibuses, and contain all back records ready for easy reference.

To summarize; the chief advantages of this system are:

Compactness. All the necessary information relating to a consumer's installation, the amount of his bills for eight years, the promptness with which he pays, etc., is on a 5 x 8 inch card. In settling complaints or disputes, this is particularly valuable.

Ease of handling. The small cards are much easier to handle, arrange and keep up to date than any kind of bound or loose leaf books. They may be classed, divided and subdivided to any extent desired, and with a minimum of labor and time. A ledger may be worked upon simultaneously by any number, by assigning the cards as desired.

Cost. While first cost of records, and even the cost of upkeep, is a minor matter so long as they serve the purpose well the cost of a card system is materially less than that of loose leaf ledgers.

The only fear in introducing the card system was the possibility of losing cards. This, however, has proved groundless, as in ten years handling of thousands of cards, not one has ever been lost.

It goes without saying that a system suited to one company is rarely, in its entirety, fitted to the needs of another utility.

The most, therefore, that the writer has attempted to do is to give a rough outline of a method which has worked well in his case, and if any members find even some small hints of value for their own use, he will be well content.

THE USE OF OIL ENGINES FOR PUMPING[1]

By C. R. Knowles

Internal combustion engines using gasoline as fuel have long been in use for railway water service. The increased consumption of water, necessitating larger pumps and heavier power, together with the increase in the cost of gasoline, has made it necessary to look to a cheaper fuel in the operation of water stations.

In order to utilize the existing equipment many of the gasoline engines now in service have been converted to kerosene and distillate engines by the addition of attachments for preheating the oil to or near the flashing point before the oil enters the cylinder. These attachments consist of generators or mixing chambers wherein the oil is heated by the exhaust of the engine. They are made in various sizes and types, both for throttling and for hit and miss governors. With these attachments the engine is generally started on gasoline and is allowed to run on this fuel until the cylinder and generator are heated, when the oil is cut in. On other types a retort is provided where the oil is converted into a vapor or gas by heating the retort with a blow torch. Either method requires from five to ten minutes to start an engine running on oil. Electric ignition is used, as with gasoline engines. Very little carbon trouble is experienced with the use of these attachments and the lubrication required is about the same as with a gasoline engine.

A series of tests of various fuels were made pumping against a total head of 61 feet, with an 8 x 10 inch single cylinder double acting pump direct connected to a 6 h.p. four cycle horizontal gasoline engine equipped to run on kerosene and distillates as well as gasoline, controlled by a throttling governor. This engine was one of the first gasoline engines ever equipped to operate on low grade oils and has been continually operated on distillates from 36° to 32° Baumé for the past six years.

[1] Presented at meeting of Illinois Section, January 25, 1916.

The fuels used were:

TABLE 1

Distillate	40.0° Baumé	Flash, 150	Burn, 145
Methyl alcohol	40.5° Baumé	Flash and burn at room temperature.	
Kerosene	46.0° Baumé	Flash, 124	Burn, 170
Gasoline	62.0° Baumé	Flash and burn at room temperature.	
Motor spirits	58.0° Baumé	Flash and burn at room temperature.	

Efficiency fuel tests

	DISTILLATE	ALCOHOL	KEROSENE	GASOLINE	MOTOR SPIRITS
Pints per hour	6.0	7.0	6.0	7.0	6.0
Pounds fuel per hour	5.145	6.062	4.943	5.373	4.755
Pounds of fuel per h.p.h.	1.91	2.22	1.91	1.97	1.74
Pump, revolutions per minute	43.35	43.32	43.54	43.72	43.79
Pumped, gallons per minute	175.0	177.8	176.8	176.8	178.1
Cost of fuel per gallon	0.04625	0.40	0.08	0.15	0.13
Cost fuel per hour	0.0347	0.35	0.06	0.1313	0.0975
Cost of fuel per h.p.h.	0.0129	0.1282	0.0220	0.0483	0.0356
Cost per 1000 gallons	0.0033	0.0327	0.0056	0.0124	0.0092
	Deg.	Deg.	Deg.	Deg.	Deg.
Temperature of cylinder start	165	90	135	46	46
Temperature of cylinder run	145	145	145	130	125
Temperature of inlet air	110	125	120	60	60

As will be seen from the above figures the distillate is the most economical of the fuels used. The cost per water horse power being 53 per cent of the cost of pumping with kerosene, and only 27 per cent of the cost of pumping with gasoline. The high cost of alcohol eliminates it as a fuel for pumping water and the result of the test is merely submitted as a comparative feature. No doubt better results could have been obtained by reducing the area of the combustion chamber as more compression is required to secure economical results from the use of alcohol in internal combustion engines. The power obtained from the use of kerosene was practically the same as from the distillate, the only difference being in the price of the two fuels. The gasoline test shows such results as might be obtained from the average gasoline engine under the same condi-

tions. The fuel known as motor spirits, which has been widely advertised as a substitute for gasoline, operates under practically the same conditions as gasoline. An objectionable feature of this oil is a disagreeable odor and it would perhaps be undesirable to use in certain localities.

A 12 h.p. four cycle gasoline engine with a hit and miss governor pulling a $7\frac{1}{2}$ x 30 inch working barrel in a deep well was equipped with a generator for burning low grade oils. Comparative tests showed that the engine consumed the same amount of 39 degrees distillate per horse power hour as gasoline. The difference in the cost of the two fuels, however, showing a saving of $.0434 per horse power hour in the use of the distillate. The cost of pumping water at this point is comparatively high, due to the fact that the water is pumped with a single acting deep well cylinder.

The tabulated results obtained follow:

TABLE 2

	GASOLINE	DISTILLATE
Pints per hour	14.0	14.0
Pounds of fuel per hour	11.746	12.005
Pounds fuel per h.p.h	3.458	3.53
Pump, revolutions per minute	24.0	24.0
Pumped, gallons per minute	124.0	124.0
Cost fuel per gallon	0.125	0.04625
Cost of fuel per hour	21.875	8.093
Cost fuel per h.p.h	0.0643	0.0209
Cost per 100 gallons water	0.0029	0.0108

The heavy oil engine is a comparatively recent development and is being extensively used in railway water stations, as well as for other service. The most popular engine of this type is the two cycle oil engine constructed in units of 50 h.p. and under, using heavy oil as fuel. This type of engine is very often confused with high compression engines operating on the Diesel principle or with the converted gasoline engine using kerosene and distillates through a carburetor or mixing valve.

The cycle of operation of the Diesel engine is to compress air to 450 or 500 pounds per square inch, generating a temperature of approximately 540°C. Into this highly heated air the fuel is injected during the return or second stroke of the piston in a finely atomized

form at such a rate as will maintain a constant temperature while burning and in such quantity as will do the required work for each stroke. The expanded gases of combustion are forced out of the cylinder during the third stroke, while the fourth stroke draws fresh air into the cylinder. This is the sequence of events in a four cycle engine.

By expelling the burned gases with fresh air the necessary functions can be performed in two strokes of the piston, producing the so called two cycle engine.

The above mentioned engine should not, however, be confused with the two cycle oil engine as used in railway and other pumping stations and termed the Semi-Diesel engine. In order to avoid the high compression pressure and the resulting complication of design necessary in the Diesel engine this so called Semi-Diesel engine has been devised, which does not compress the air sufficiently to raise the temperature to such a point that it will spontaneously ignite the injected fuel. It is this type of engine which we have to deal with, particularly with the two cycle valveless injection engine, in which the compression has been reduced, adding the required temperature in a heated combustion chamber. This engine is governed by throttling the oil supply and ignition is accomplished by means of a hollow ball. This ball is heated by a blow torch before starting, but after the engine is running the heat is maintained by the successive explosions. The fuel is introduced through fuel valves similar to the Diesel engine, but much less compression of air is required. The compression of the Semi-Diesel engines being from 80 to 130 pounds. Crank case compression is $1\frac{3}{4}$ to $3\frac{1}{2}$ pounds.

Although these engines have a theoretically less efficient heat cycle than the Diesel they gain in simplicity of construction.

Intelligent lubrication is essential to the proper operation of the oil engine. Improper lubrication contributes largely to oil engine trouble. The high speeds and temperature at which these engines work necessitate a continuous and skillful use of good oil. A great deal depends upon the proper lubrication of an engine of this type and the prevention of the carbon forming in the cylinder. The destruction of the lubricating oil by combustion cannot be prevented. Just what occurs to the oil in an internal combustion engine cannot be entirely explained, but there is no doubt that a great deal of it is burned along with the fuel oil and as long as this is true it is necessary that complete combustion takes place, in order

that a residue of unburnt oil is not left in the cylinder in the form of carbon.

The lubrication of the steam engine or pump is comparatively simple. In steam engines there is a certain amount of moisture to assist lubrication, but the flames of an oil engine dry the internal surfaces and unless the proper amount of oil is applied, the cylinder, piston and rings soon begin to suffer. In a steam engine or pump the temperature will at the most reach about 500 degrees while in an oil engine it rises to as high as 2500 degrees. Added to this is the fact that the piston speed of an internal combustion engine is from three to four times that of a steam engine or pump. Consequently the oil engine requires a different method of lubrication and a great deal more of it.

Engines of this type are liable to suffer from carbon trouble and resultant deterioration due to the fact that an excess of oil injected into the cylinder breaks up into volatile compounds, such as the naphthas, heavy tar like oils and free carbon.

Overloading the engine also will cause carbon trouble. When the engine is working up to its maximum power, a momentary overload will cause an excess of oil, and the resultant accumulation of carbon due to the fact that the oil engine is not flexible enough to adjust itself instantly to the varying loads, as does a steam engine or pump.

The carbon troubles may be reduced to the minimum by the use of the proper oil. Fuel oils vary in quality as do hard and soft coal and even to a greater extent. As a result some oils are better suited for use in oil engines than others. While it is possible to burn almost any oil that will flow freely, the best results are to be obtained from oils of a parafine base from 30 to 36° Baumé.

A number of tests were conducted on a 25 h.p. oil engine with a 10 x 14 inch cylinder belted to a 10 x 12 inch duplex power pump, using seven different kinds of oil, ranging from a heavy fuel oil of an asphalt base to a light distillate of a parafine base. A brief description of the oils used follows:

No. 1. Diesel fuel oil, 26° Baumé made from asphaltum base crudes from Texas and Louisiana fields.

No. 2. Gulf fuel oil, 24° Baumé, made from asphaltum base crudes from Oklahoma fields.

No. 3. Narico distillate, 39° Baumé, made from semi-parafine base mid-continent crudes.

No. 4. Motor oil, 42° Baumé, made from parafine base crudes from Cushing Oklahoma fields.

No. 5. Navy fuel oil, 26° Baumé, made from asphaltum base crudes from Texas and Oklahoma fields.

No. 6. No. 1 fuel oil, 32° Baumé, a nonsulphur oil parafine base from Illinois crudes.

No. 7. Kentucky crude oil 32.5° Baumé parafine base.

The following table gives the results obtained from the use of the above oils. The costs given cover the fuel only:

TABLE 3

	1	2	3	4	5	6	7
Gallons of oil used per hour.	1.51	2.29	2.04	1.88	2.19	2.00	2.10
Pounds of oil used per hour.	11.30	17.33	14.07	12.20	16.38	14.40	15.07
Pounds of oil used per w.h.p.	1.02	1.12	0.98	0.80	1.01	0.96	0.85
Engine r.p.m....	346.0	337.0	345.0	345.0	342.0	338.0	328.0
Pump r.p.m.....	40.0	39.0	40.0	40.0	40.0	39.0	38.0
Gallons pumped per minute...	444.0	603.0	583.0	592.0	586.0	580.0	577.0
Cost of oil per gallon........	0.029	0.029	0.031	0.03	0.029	0.025	0.016
Cost of oil per hour.........	0.044	0.066	0.063	0.056	0.063	0.05	0.035
Cost per 1000 gallons.......	0.0016	0.0019	0.0022	0.0016	0.0018	0.0015	0.0009

While these tests are not conclusive they indicate the wide range of fuels it is possible to burn in these engines.

The following tables give the result of tests conducted in pumping with 4 inch centrifugal pumps using two cycle Semi-Diesel oil engines for power, one pump being driven by a 25 h.p. horizontal engine and the other by a 25 h.p. vertical engine, both pumps being belt driven.

Table 4 gives the result of one hour's run, while table 5 gives the hours run and cost for a period of four months for each engine.

Tables 6 and 7 show the results obtained in pumping with a 25 h.p. horizontal two cycle heavy oil engine belted to a 10 x 12 inch double acting duplex power pump and a 30 h.p. vertical two cycle heavy oil engine belted to a 11 x 12 inch single acting triplex power pump.

TABLE 4

Test one hour's run

	HORIZONTAL ENGINE	VERTICAL ENGINE
R.p.m. engine	315.0	380.0
R.p.m. pump	1587.0	1320.0
Gallons pumped per minute	571.0	571.0
Total head in feet	77.38	79.69
Fuel oil consumed in gallons	2.25	2.65
Water horse power	11.15	11.5
Brake horse power	21.4	22.1
Cost fuel oil per million gallons	$1.67	$1.97.
Cost of fuel oil per gallon	0.0253	0.0253
Cost per h.p.h	0.0026	0.0030

TABLE 5

Cost of fuel and lubricants four months' run each engine

	HORIZONTAL ENGINE	VERTICAL ENGINE
Total number of hours run	331	316
Gallons water pumped	9,930,000	9,480,000
Cost of kerosene	$3.78	$1.50
Cost of fuel oil	18.01	18.47
Cost of lubricants	9.20	10.20
	$30.99	$30.17
Cost per 1,000,000 gallons	$3.12	$3.18

TABLE 6

Test one hour's run

	DUPLEX PUMP HORIZONTAL ENGINE	TRIPLEX PUMP VERTICAL ENGINE
R.p.m. engine	342	396
R.p.m. pump	40	44
Gallons pumped per minute	586	640
Total head in feet	104	106
Fuel oil consumed in gallons	2.19	2.70
Water horse power	15.33	17.5
Brake horse power	20.44	23.33
Cost fuel oil per million gallons pumped	$1.80	$2.00
Cost fuel oil per gallon	0.029	0.029
Cost per h.p.h	0.0031	0.033

TABLE 7

Cost of fuel and lubricants four months' run each engine

	DUPLEX PUMP HORIZONTAL ENGINE	TRIPLEX PUMP VERTICAL ENGINE
Total number of hours run	687	677
Gallons water pumped	24,732,000	24,372,000
Cost of kerosene	8.52	9.78
Cost of fuel oil	26.26	31.37
Cost of lubricants	17.10	22.04
Total cost	51.88	63.19
Cost per million gallons	$2.09	$2.54

Table 6 giving the results for one hour's run and table 7 cost for a period of four months for each engine.

Although the oil engine cannot yet be considered as fully developed, it has passed the experimental stage, and while it is perhaps, not as reliable under all conditions as a steam engine or pump, much of the prejudice against the oil engine is undoubtedly due to lack of experience in handling. With the present imperfect knowledge of what the engine is capable of doing and of what particular oils may be burned in it, one cannot speak conclusively, but there is no doubt that the future of the engine is assured.

THE WATER SUPPLIES OF INTERSTATE COMMON CARRIERS ON THE GREAT LAKES[1]

By H. P. Letton

The fact that drinking water supplies on board lake vessels were often contaminated and that such contamination undoubtedly caused a marked increase in the typhoid rate among sailors was pointed out as early as 1909 by Cobb. The matter was also discussed by Young in 1910, and deValin in 1914. It was not, however, until the Interstate Quarantine Regulations were amended so as to put the control of drinking water supplies aboard interstate common carriers under the supervision of the United States Public Health Service that any active measures were taken towards bettering conditions.

The Interstate Quarantine Regulations provide that all drinking water furnished for use of crews or passengers on any common carriers engaged in interstate traffic shall conform to a bacteriological standard promulgated by the Secretary of the Treasury. This standard has been discussed before the American Water Works Association by Monfort, Bartow and others. Briefly, the standard requires that the total number of bacteria on agar at 37°C. shall not exceed one hundred per cubic centimeter, and not more than one out of five 10 cc. portions of any sample examined shall show the presence of organisms of the bacillus coli group.

Following the promulgation of the Interstate Quarantine Laws and Regulations relating to common carriers and in order to facilitate their enforcement, the Continental United States was divided into twelve districts, known as Interstate Sanitary Districts (see fig. 1). The District of the Great Lakes embraces parts of the States of New York, Pennsylvania, West Virginia, Indiana, Ohio, Illinois, Wisconsin and Minnesota, and the entire State of Michigan.

[1] This paper is an abstract of an advance copy of a report on the operations of the Sanitary District of the Great Lakes during the past season. The report is the joint authorship of Surgeon J. O. Cobb, Assistant Surgeon C. L. Williams, and the speaker, all of the United States Public Health Service. Presented at meeting of the Illinois Section, January 25, 1916.

Fig. 1. Map Showing Interstate Sanitary Districts, District of Great Lakes Cross Hatched

The headquarters and laboratory for this District are at the United States Marine Hospital, 4141 Clarendon Avenue, Chicago, Illinois. The work is under the direct charge of Surgeon J. O. Cobb, United States Public Health Service.

While the regulations apply to both vessels and trains, during the past summer no attempt was made to study the train waters in this District, all the energy being directed towards a solution of the ship problem. Inspections were made and samples collected from most of the passenger vessels and from some freight vessels on the Great Lakes. The scope of this work will be briefly outlined.

PRESENT METHOD OF OBTAINING DRINKING WATER ON LAKE VESSELS

There are two general methods of obtaining drinking water on board lake vessels, the first and most common being by pumping or by gravity through a seacock in the hull of the vessel, and the second by filling the drinking water tanks through a hose from a hydrant on shore. The seacocks vary in size from 2 to 10 inches and are usually placed at a depth of about 8 feet below the water line. In many cases, the storage tanks are located below the water line, and it is possible to fill them by gravity. In other cases, the water is pumped into the tanks by the general service pump. A few vessels are equipped with special pumps used only for handling the fresh water, and in such instances the tanks are filled by these pumps. In the latter case, it is quite common to find special seacocks used only for taking in the drinking water supply.

The drinking water storage tanks are usually placed near the keel of the vessel, although in some cases they are placed on an upper deck. They are constructed of galvanized iron or sheet steel, usually cylindrical in shape, and have capacities varying from 2000 to 10,000 gallons. In a few cases, tanks are built in the fantail of the vessel by placing a bulkhead across the ship and allowing the hull to form a part of the tank. Tanks of this character are more or less liable to contamination. In fact, on two vessels, soil pipes from water closets were found to pass through the tank, and in one case leakage from around the rudder post polluted the drinking water. Very few tanks are lined, though sometimes they are given a coat of "Bitumastic Enamel" or of neat cement.

The water of the Great Lakes contains so little sediment that it

is unnecessary to physically clean the tanks except at long intervals. On many freight vessels, it was found to be the custom at frequent intervals for a man to go inside the tanks and scrub them, but it is believed that such cleaning is dangerous, because of the chance of contamination from a possible typhoid carrier. It was recommended that the vessels using this method discontinue it and substitute therefor sterilization of the tank by dosing it with a large amount of calcium hypochlorite.

DISTRIBUTING SYSTEMS

Although on most vessels there are several systems of water supply, the only one of sanitary significance is the fresh or drinking water which supplies drinking fountains, kitchens and lavoratories.

This water is always distributed either by gravity from a storage tank located on the upper deck or by a special distributing pump which maintains a constant pressure in the system. When the tanks are filled by gravity, there is always a special distributing pump (see fig. 2). When the tanks are filled by general service pump, the water is either distributed by gravity or by a special pump (see figs. 3 and 4). When a special pump is used for filling the tank, the water is distributed by this same pump, although in some cases it may supply a gravity tank on the upper deck. The greatest opportunity for the contamination of the drinking water supply occurs when the tanks are filled by the general service pump. This pump is often used for washing down decks while the vessel is lying in port. After leaving port, it is used for shooting ashes and other purposes for perhaps an hour before the drinking water tanks are filled, it being thought that in this time the pump and piping system are thoroughly cleansed and free from contaminating water. When we consider, however, that on some vessels the suction pipe is 8 inches in diameter and perhaps 50 feet long and that the water passes through a manifold system containing numerous bends, it is obvious that there is a considerable opportunity for polluting matter to remain in the piping system and be carried into the drinking water tanks when they are filled (see figs. 5 and 6). In those cases where special pumps are used for filling the tanks, the seacock is often left open all the time and the valve near the pump is opened or closed as water is taken in. This means that while the vessel is lying in dock, polluted water

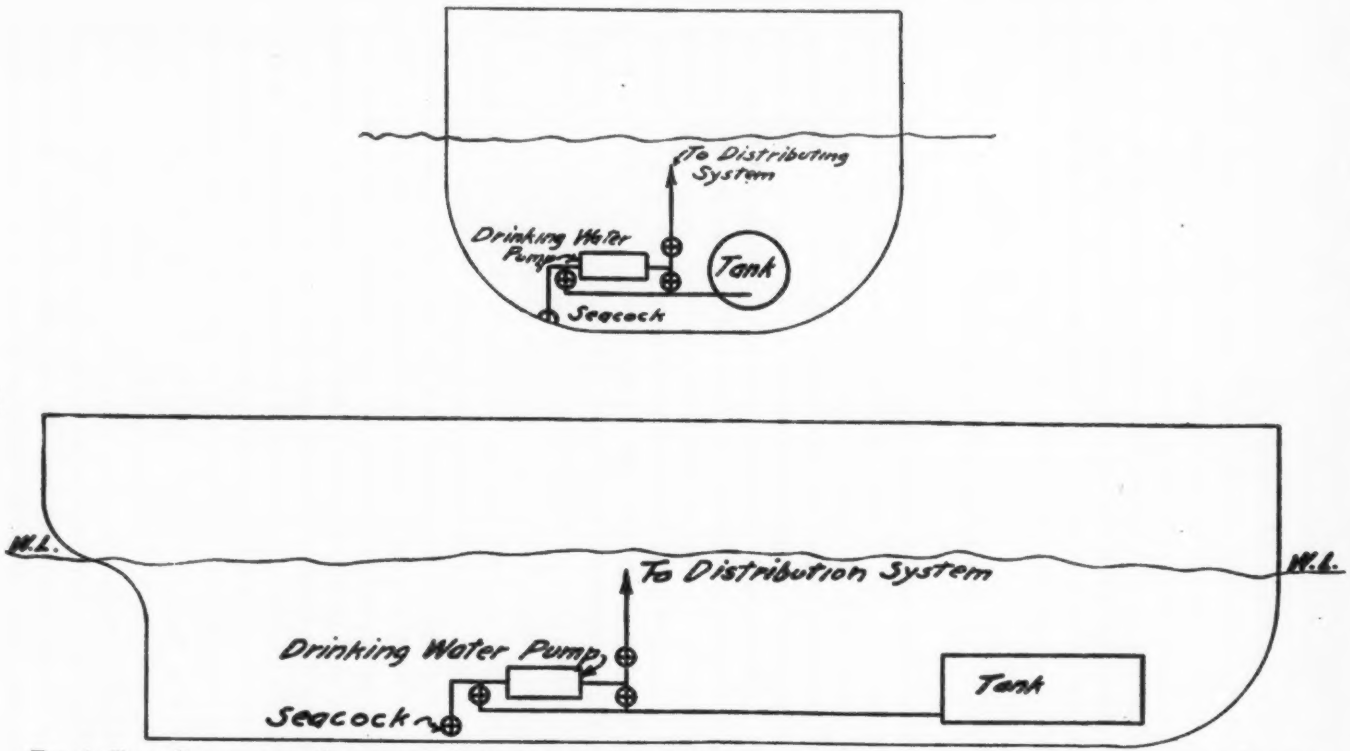


FIG. 2. TANK FILLED FROM SEACOCK BY GRAVITY OR BY SPECIAL DRINKING WATER PUMP. WATER DISTRIBUTED BY SPECIAL DRINKING WATER PUMP

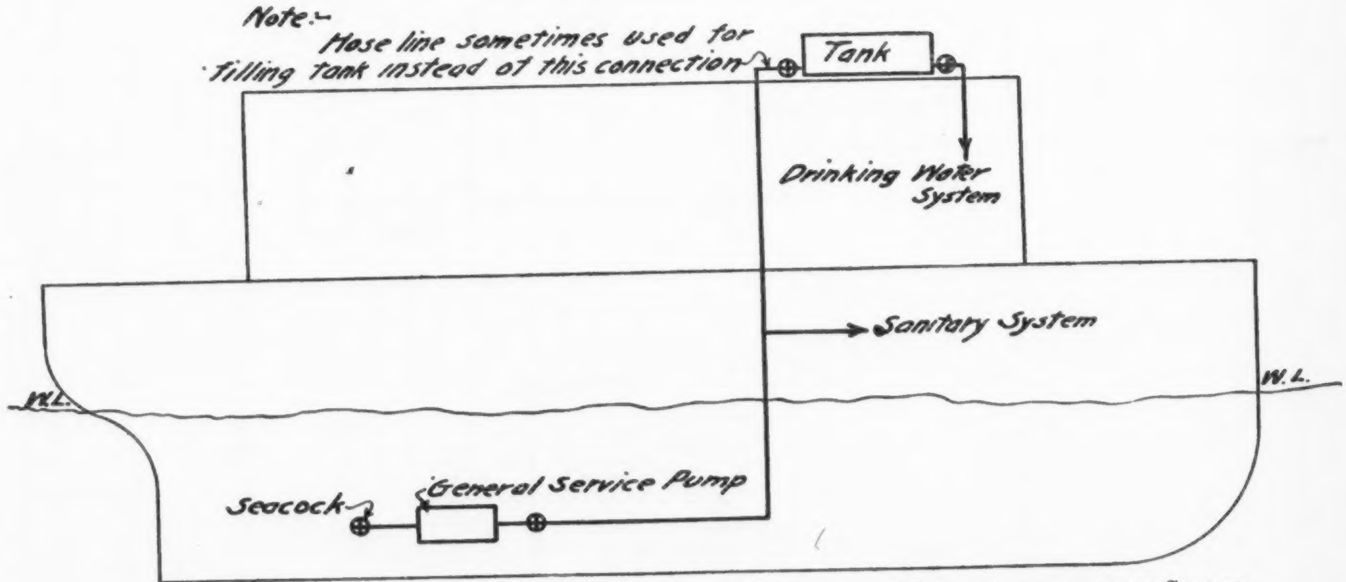


FIG. 3. TANK FILLED FROM SEACOCK BY GENERAL SERVICE PUMP—DRINKING WATER DISTRIBUTED BY GRAVITY

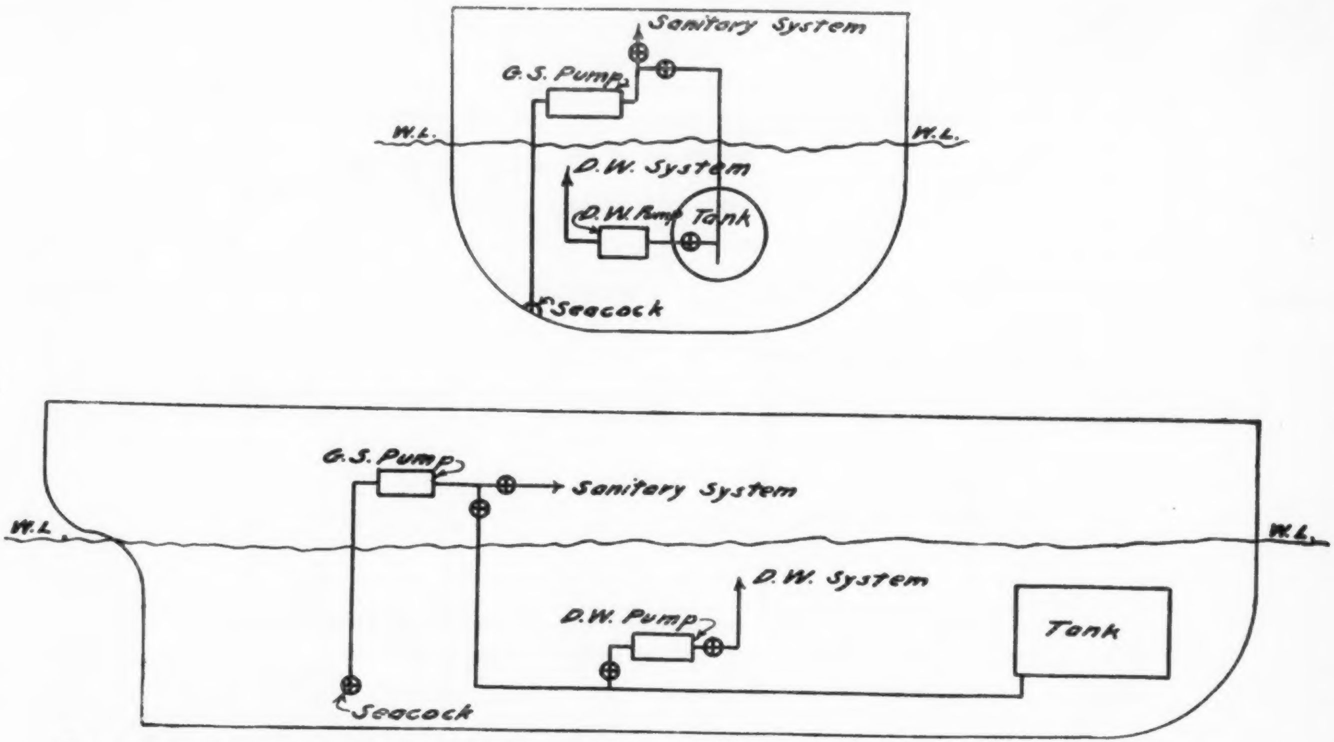


FIG. 4. TANK FILLED FROM SEACOCK BY GENERAL SERVICE PUMP—DRINKING WATER DISTRIBUTED BY SPECIAL PUMP

can enter the seacock and suction line, and upon filling the tanks some of this is carried in. This danger is much aggravated by the fact that at almost every port on the Great Lakes the vessels lie in very badly sewage polluted waters.

On some vessels in order to protect themselves against pollution of this kind, there has been placed between the seacock and the valve near the pump a small drain pipe. With this arrangement, the valve and seacock are kept closed when not taking water from the lake and the drain pipe open, so that if there is any leakage through the seacock it will drain to waste.

Most vessels having a gravity tank on the upper deck, fill it directly from the pump by means of a pipe connection controlled by a valve. On other vessels, the only way to fill the tanks is by means of a hose, which guards against the accidental filling of this tank while lying in port (see fig. 3). That this matter is important is borne out by the fact that at times water is pumped into the tanks when lying at dock. In fact, during one of the inspections made by the writer, a tank of this kind was found filled with Chicago River water due to the carelessness of a watchman in opening the valve leading to the tank, while washing down decks. From statements made by ships' officers, and others, it is evident that occurrences of this kind are by no means rare.

When the drinking water tanks are filled from shore, it is done either by carrying the water through a fire hose directly from the hydrant to the tank or by connecting the hose on to the distribution system. Most vessels which fill their tanks from shore have a connection between the general service pump and the tanks, but in many cases, this connection has been protected from contamination by means of two valves and a drain pipe as described heretofore in connection with seacocks.

OPPORTUNITIES FOR CONTAMINATION

The opportunities for contamination of the drinking water of vessels are:

1. From faulty seating of valves, or failure to close valves while lying in polluted water.

2. Since in most vessels the seacocks are aft of amidships there is a possibility of pumping in fecal matter discharged from toilets near the bow.

3. It is often difficult for a vessel to obtain the necessary amount of drinking water at a sufficient distance from contaminated harbors, and this matter is aggravated by the fact that the engineer can not always tell exactly where a vessel is at any time. There is also the possibility of some accident in the engine room which may cause the engineer to forget to close the seacock as the vessel approaches a polluted harbor.

4. There is also the chance of picking up contamination in the wake of other vessels, or when one vessel is towing another. That this is a real danger has been brought out by testimony before the International Joint Commission.

SUMMARY

As a result of the above statements, it can be seen that it is an impossibility for any vessel operating on the Great Lakes, using the methods at present in vogue, to obtain water absolutely free from contamination. It is therefore necessary, in order to always furnish water of the required purity, for each vessel to be equipped with some suitable form of water purification. Some vessels have already made an attempt along this line, and the apparatus in use will be briefly discussed.

FILTRATION

The most common method used in attempting to purify the drinking water on board vessels is that of filtration through small pressure rapid sand filters, there being about thirty vessels using filters of this kind. These filters are either used as a complete process in themselves or as a preliminary step in some other method of purification. The time will not be taken to discuss the operation of this type of filter as it is generally known that such pressure rapid sand filters using an alum shunt feed box for adding coagulating chemical are very inefficient. A total of 213 tap samples were collected from vessels using small rapid sand filters only, and of this total less than 39 per cent conformed to the standard. Two boats were equipped with rapid sand filters using an electric current for producing a coagulant of iron hydrate, but the results on these boats were no better than on the ordinary type.

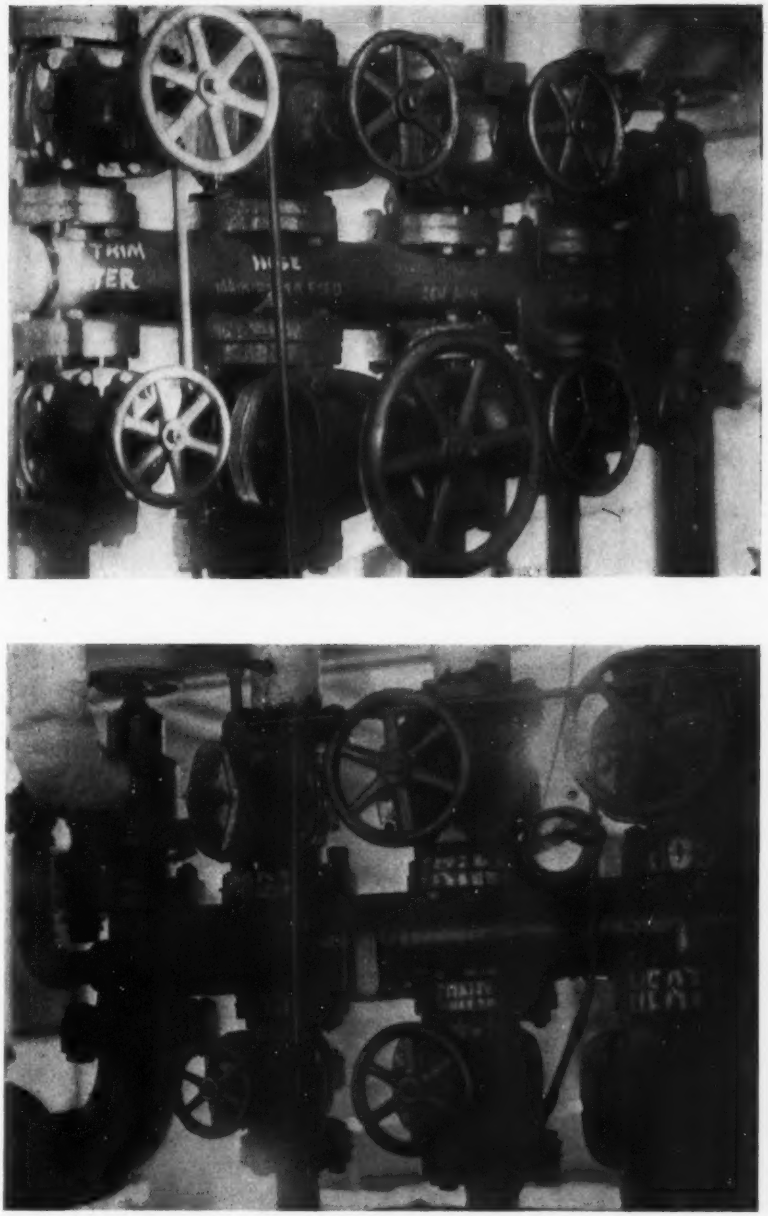


Fig. 5. Photograph of Manifolds on Two Vessels—Lower Photograph Shows Wheel on Valve Controlling Line Leading to Forward Tank Removed—Drain Valve for Detecting Leakage Can Be Seen above this Valve.

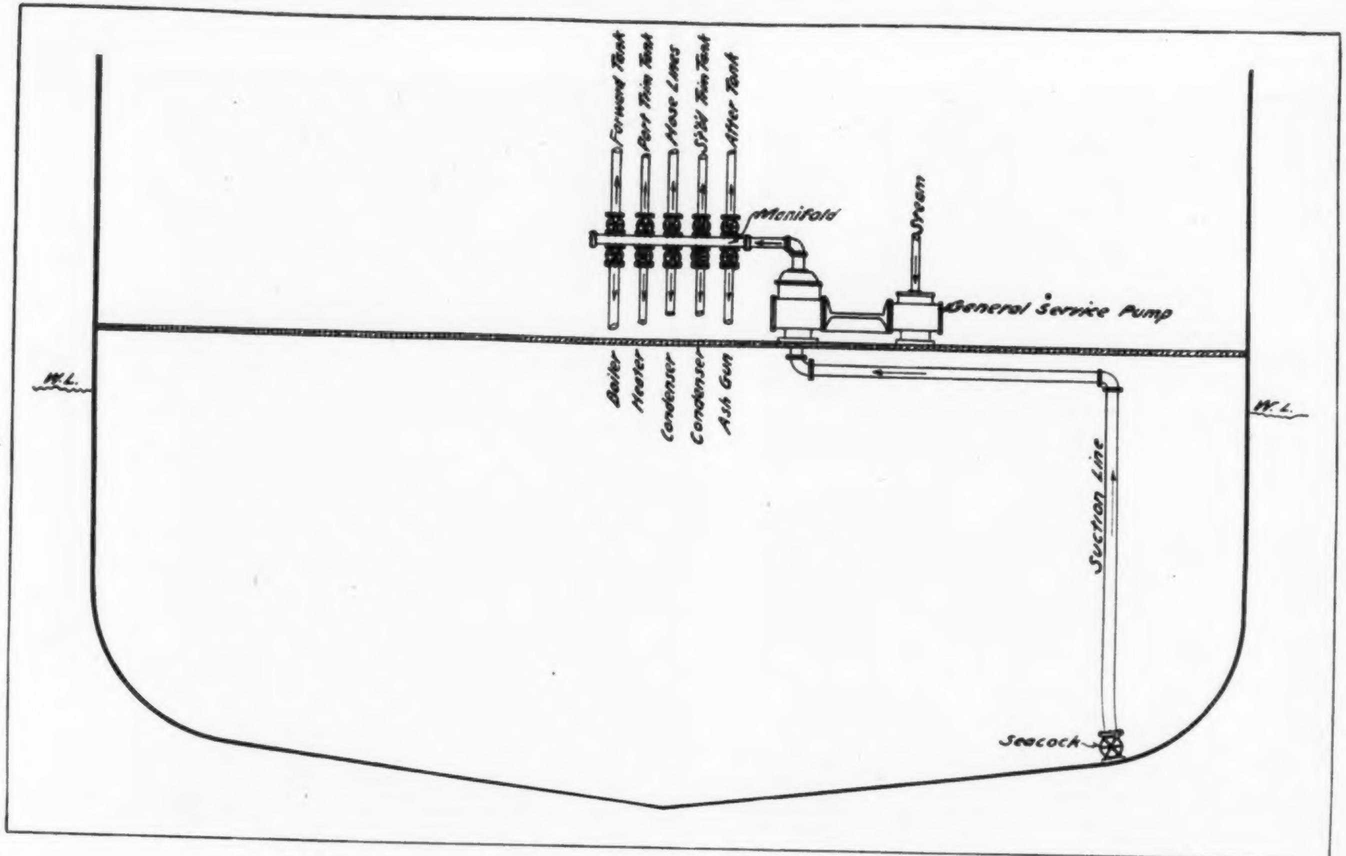


FIG. 6. CROSS SECTION OF VESSEL SHOWING SEACOCK, SUCTION LINE AND MANIFOLD.

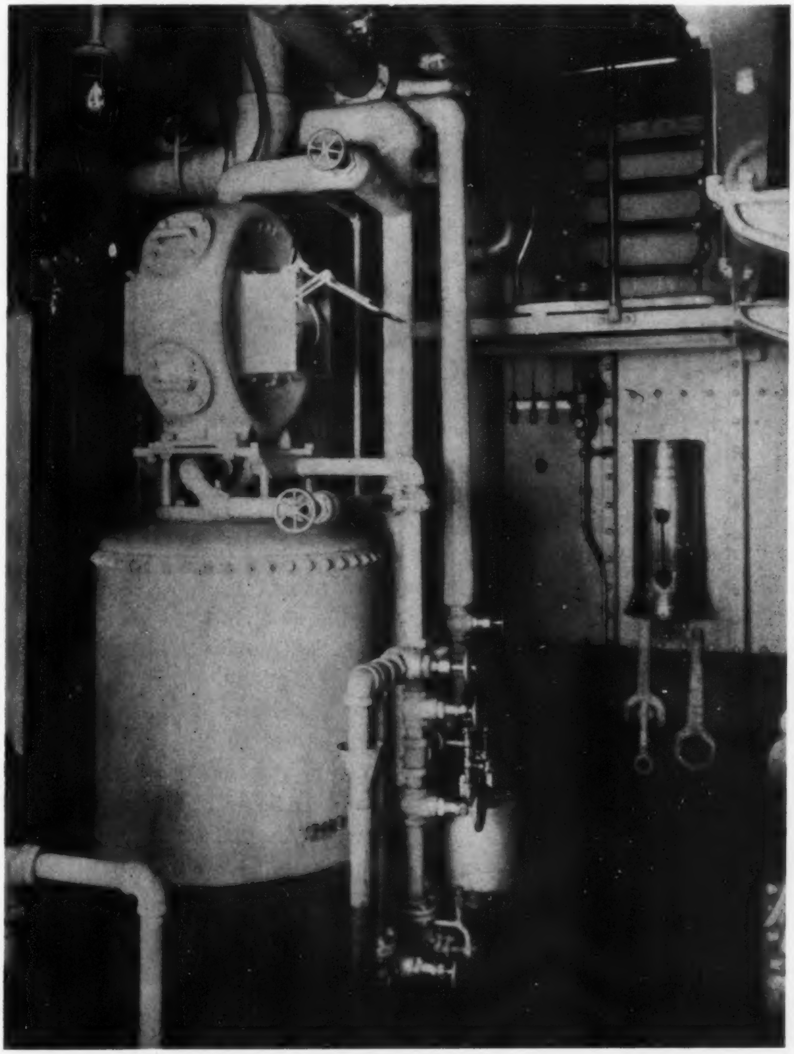


FIG. 7. RAPID SAND PRESSURE FILTER WITH SHUNT FEED COAGULANT BOX AND PRESSURE TYPE ULTRA VIOLET RAY APPARATUS ON STEAMSHIP ALABAMA.

ULTRA VIOLET RAY STERILIZATION

Thirteen vessels were equipped with an apparatus for treating the water with ultra violet rays. In each case, the water was first passed through a rapid sand pressure filter in order to remove any turbidity. Most of the vessels used the pressure type of apparatus in which the water was caused to pass by means of a series of baffles, in thin sheet through the ultra violet rays (see figs. 7 and 8). The lamps for furnishing the rays were mercury vapor lamps of the Cooper-Hewett type constructed of quartz, which allows the passage of the ultra violet rays. These lamps, with one exception, were operated on a current of 110 volts. There were a great many defects in the apparatus as in use during the past summer, but no attempt to enumerate them will be made at this time. Suffice it to say that the company manufacturing this apparatus has as a result of the findings of this laboratory made a considerable number of changes, all of which were for the purpose of increasing the intensity of the light and of making the apparatus absolutely automatic and fool proof in operation (see fig. 9).

CHLORINE DISINFECTION

Five vessels treated their drinking water with calcium hypochlorite by adding a small dose to the storage tanks each time they were filled. Although hypochlorite is an efficient sterilizing agent when properly handled, its use on vessels is not to be recommended, inasmuch as it requires constant supervision for efficient results and since supervision of this kind is not possible on board ship.

On one vessel, there was installed late in the season an apparatus for treating water by means of liquid chlorine. This result was accomplished by making up with the chlorine gas a solution of chlorine water which was fed into the system in proportion to the amount of water being used. The apparatus was quite complicated and somewhat fragile and was broken during a high sea before any reliable conclusions could be drawn as to its efficiency. As a general thing, however, any treatment of this kind, which is dependent for its efficiency upon the human element, is bound to fail at times. The engineer's duty is first to run his engine and the water supply is more or less of a secondary consideration to him and will be neglected in case of unexpected trouble in the engine room.

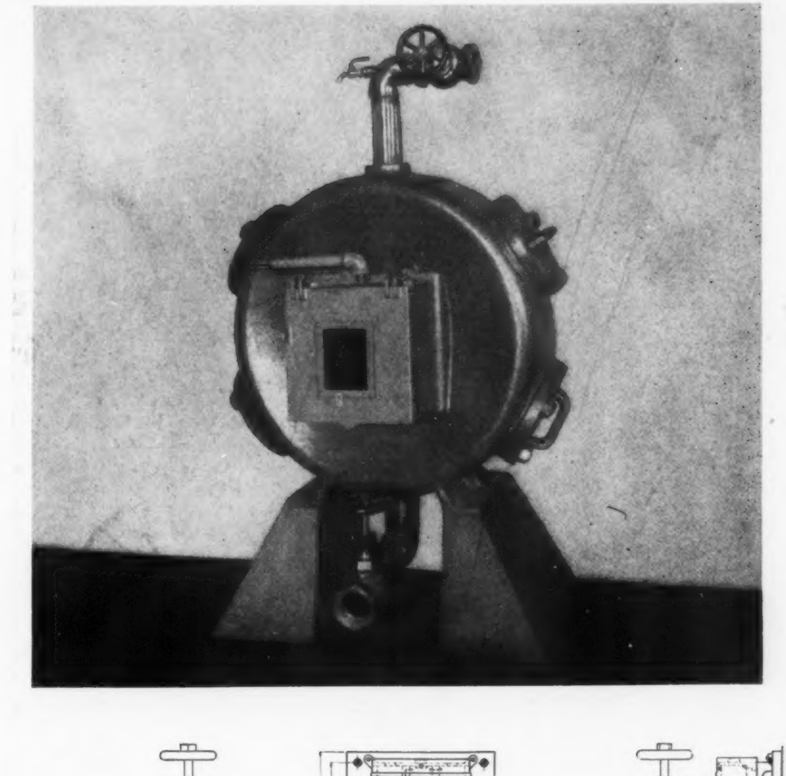


FIG. 8. PHOTOGRAPH AND DRAWING OF ULTRA VIOLET RAY STERILIZER OF THE PRESSURE TYPE—IN THIS APPARATUS THE PISTOL TYPE OF LAMP WAS USED

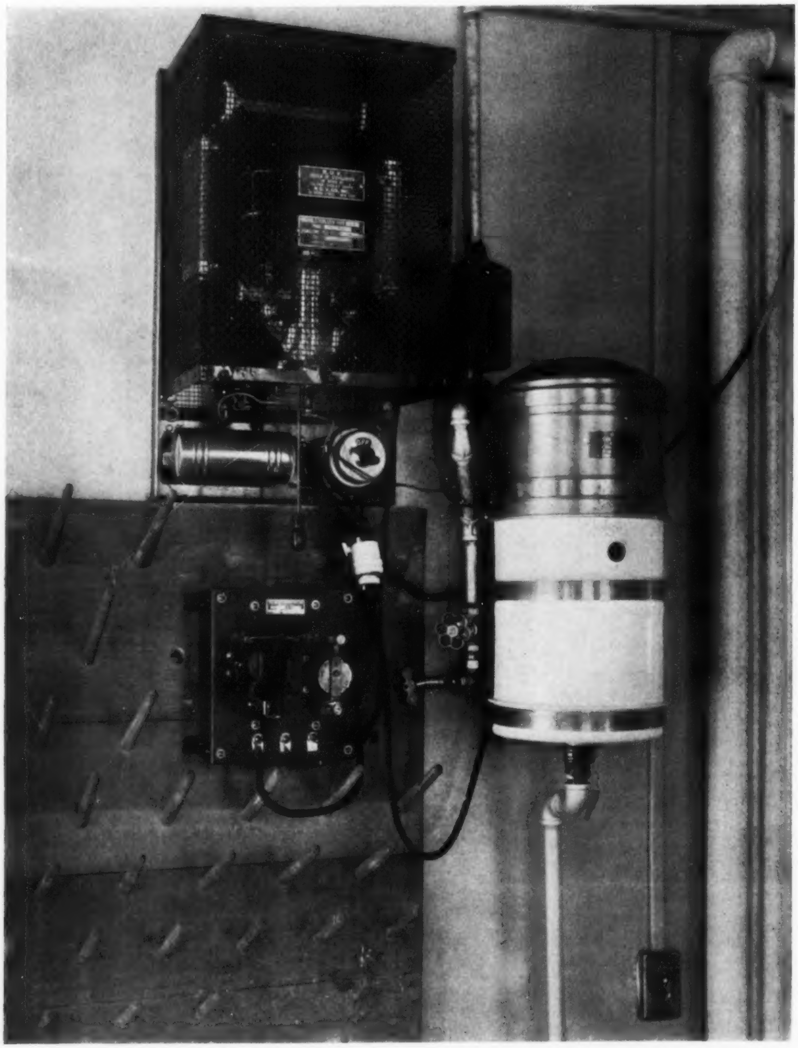


Fig. 9. Photograph of Ultra Violet Ray Sterilizing Apparatus of the Gravity Type Equipped with Automatic Tilted Lamp and Solenoid Operated Water Valve so Arranged that no Water Can Pass the Apparatus unless the Current is on and the Lamp at its Maximum Intensity.

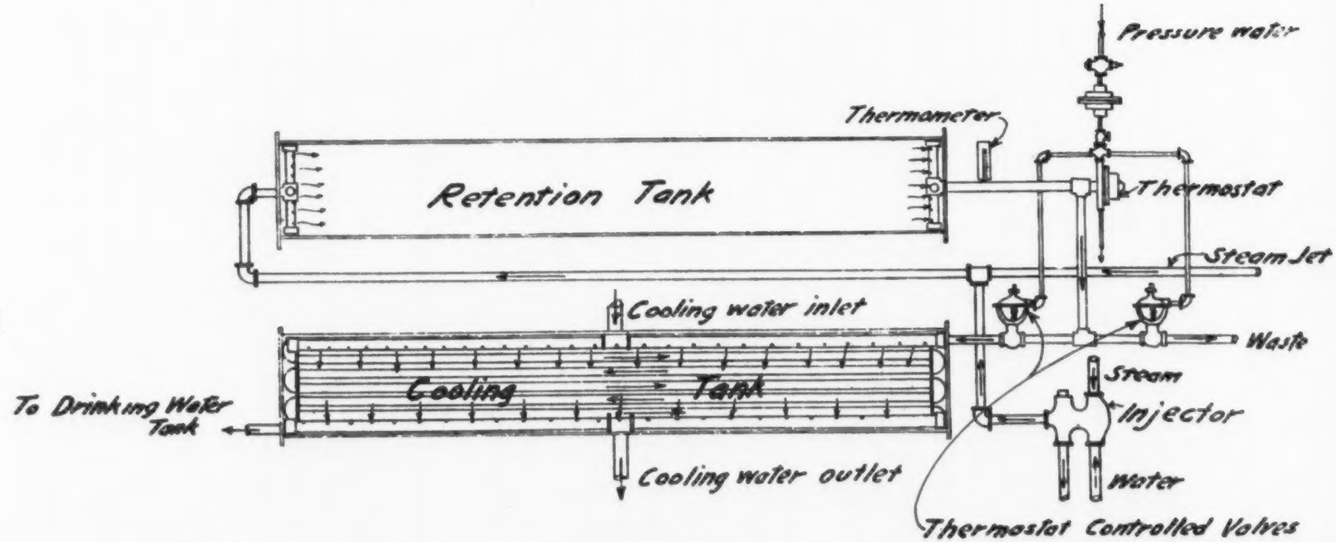


FIG. 10. DIAGRAM OF APPARATUS FOR DISINFECTING WATER BY STEAM JET EQUIPPED WITH DEVICES TO MAKE IT AUTOMATIC AND FOOL-PROOF IN OPERATION

STERILIZATION BY HEAT FROM STEAM JET

Five vessels treated their water by heating it with a steam jet. In this apparatus the water was first pumped through a seacock with a steam injector, after which a steam jet was added, increasing the temperature of the water to around 220°F. After reaching this temperature, the water was passed through a coil around which was circulated cold water, which cooled the drinking water down to about 130°F., after which it was run to the storage tanks. The results of this apparatus, so far as B. coli were concerned, were good, but due to the fact that the water ran to the storage tanks at a high temperature aftergrowths took place, which often gave extremely high counts on agar at 37°C. In order to produce efficient results, it was necessary for the engineer to carefully watch the apparatus while taking water in to see that none which was not heated to the requisite temperature reached the storage tanks. With a few modifications, the apparatus could be made fool proof and automatic in operation (see fig. 10). These improvements would consist of adding a supplementary tank between the injector and the cooling tank, which would retain the water at its maximum temperature for perhaps five minutes. At the outlet of this retention tank would be placed a thermostat, which would automatically operate a waste valve and the valve leading into the cooling tank, so that when the water was not up to the requisite temperature it would be run to waste.

SUMMARY OF BACTERIOLOGICAL RESULTS

A total of about 1000 samples were collected and examined from 74 passenger vessels and 68 samples were collected and examined from 33 different freight vessels. A series of vessels equipped with various types of purification apparatus were selected for intensive study. From these vessels samples were collected from many points in the purification systems in order to determine their efficiency.

A total of 155 tap samples were collected from passenger vessels having no form of treatment. About 22 per cent of these samples conformed to the standard. A total of 521 tap samples were collected from vessels having treatment and about 40 per cent of these conformed to the standard. From freight vessels, all of which

were without treatment, 57 samples were collected, of which about 19 per cent conformed to the standard. Of the two most common methods of purification, rapid sand pressure filters and ultra violet light, in each case less than 39 per cent conformed to the standard (see figs. 11 and 12).

CONCLUSIONS

From the foregoing, the following conclusions are derived:

1. The type and location of seacock and the arrangement for filling the tanks play but a small part in the character of the water obtained.

2. The types of purification apparatus in use on vessels of the Great Lakes at the present time are woefully inefficient. There is not a method in use that can be depended upon to deliver a safe water at all times.

3. The route of the vessel plays some part in the character of the water supply, especially because of the places of docking.

4. It is an impossibility to obtain a drinking water for boats directly from the lakes that will at all times conform to the Treasury Department standard.

Therefore, it is necessary that every vessel on the Great Lakes, in order to comply with the law, install a form of water purification apparatus, which shall be so constructed that it cannot under any conceivable circumstance deliver a water which will not conform to the government requirements. This will necessitate an apparatus that will be entirely automatic in action and which will not depend for its efficiency upon the human agency.

Undoubtedly, the ideal form of water purification apparatus which will meet the above requirement is the still. Steam heated water stills are now on the market that are absolutely automatic in action and impossible of producing any water except that which is bacteriologically pure. Stills are in use at the present time on practically all ocean going vessels, and there is no reason why they are not applicable for lake vessels. A big advantage of stills is that no attention need be paid to the place of taking water and the stills can operate twenty-four hours a day. There are only three disadvantages of stills, and these are not of sanitary significance. They are the operating cost, the possibility of corrosion of pipes or tanks, and the possibility of producing a flat or unpalatable water.

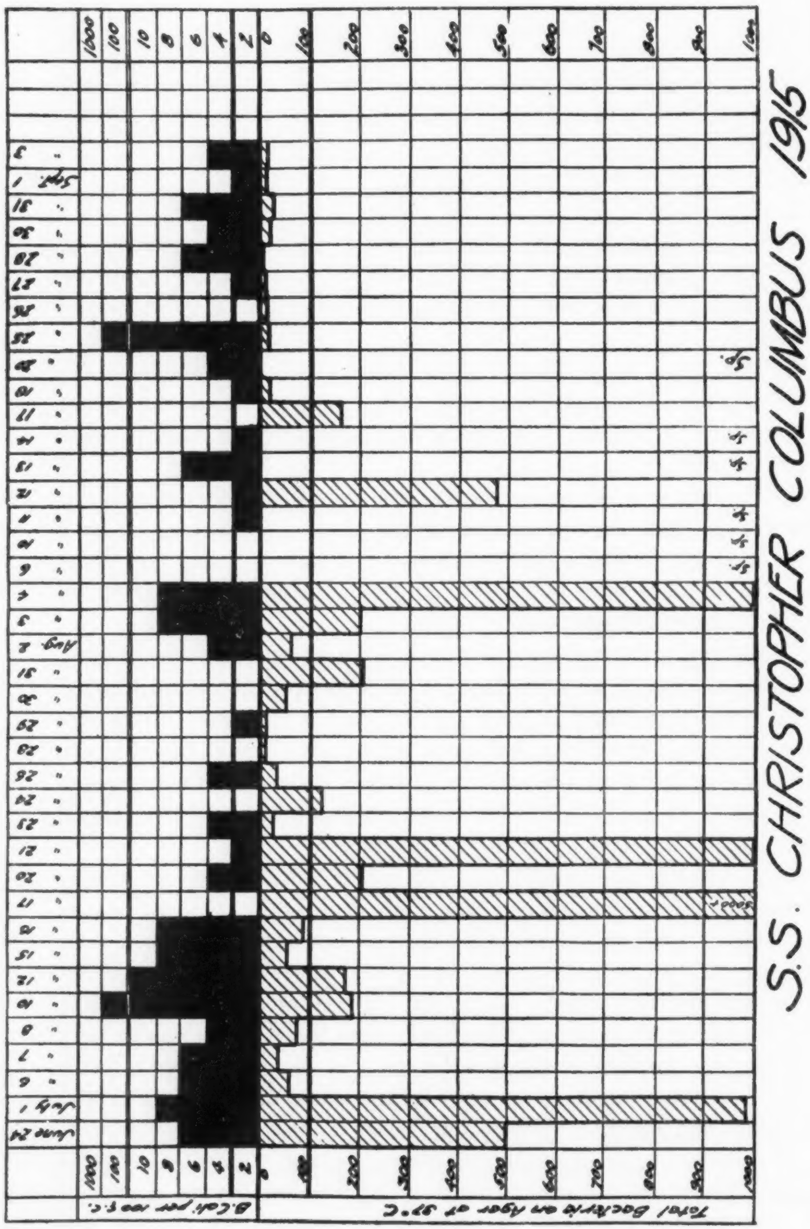


FIG. 11. GRAPHICAL CHART SHOWING RESULTS OF ANALYSES OF TAP SAMPLES FROM STEAMSHIP "CHRISTOPHER COLUMBUS"—THESE RESULTS ARE TYPICAL OF SIMILAR VESSELS

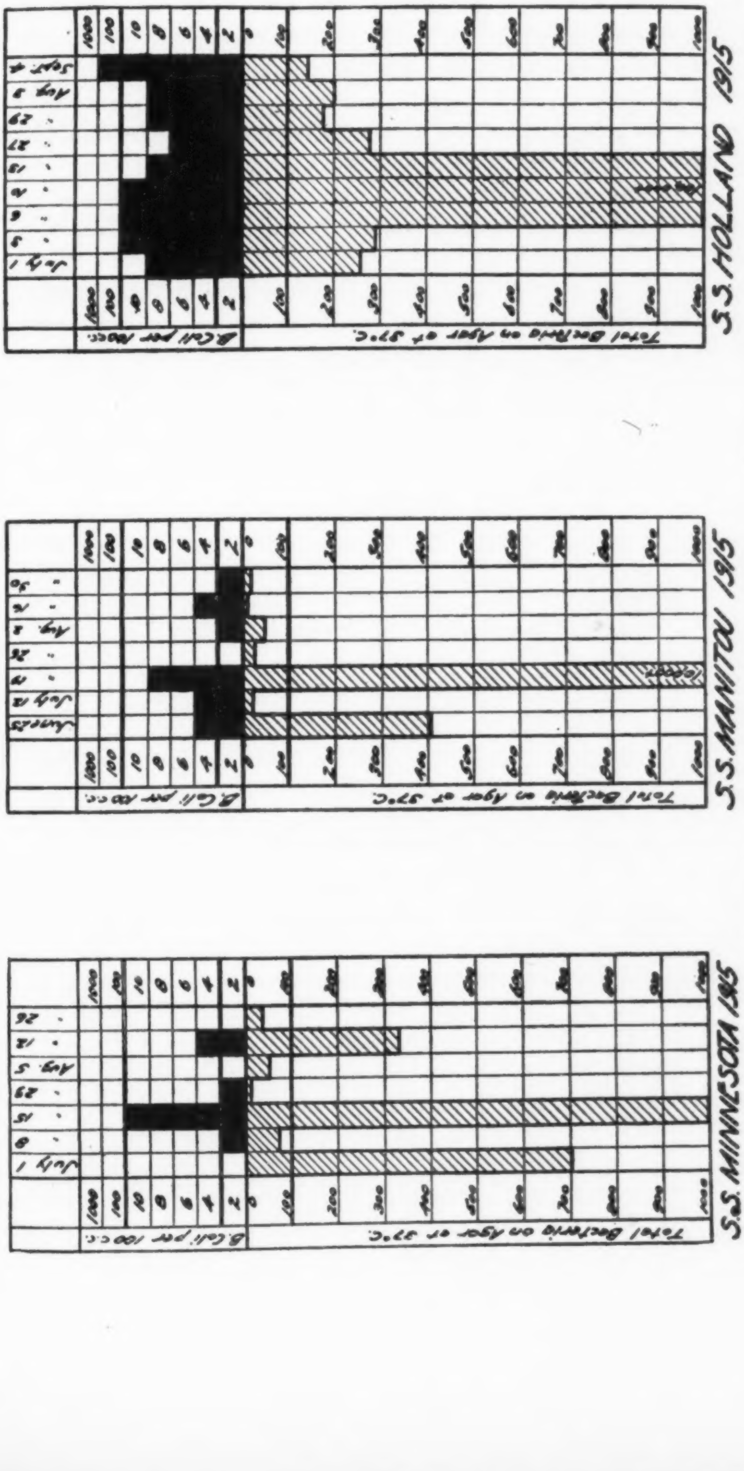


FIG. 12. GRAPHICAL CHART SHOWING RESULTS OF ANALYSES OF TAP SAMPLES FROM STEAMSHIPS "MINNESOTA," "MANITOU" AND "HOLLAND"—ALL THESE VESSELS WERE EQUIPPED WITH RAPID SAND PRESSURE FILTERS ONLY

The scheme heretofore outlined of pumping water by means of an injector would also be perfectly reliable and would produce a palatable water which would meet the requirements, without excessive cost.

Tests now being carried on at the laboratory indicate that the ultra violet ray apparatus with devices to prevent overloading and to prevent any water passing into the distribution system when the light is not at its maximum intensity will also give satisfactory results.

Outside of the above three methods, there are, in their present state of development, none which will under all circumstances produce a water meeting the government requirements.

THE BUBBLY CREEK WATER SOFTENING PLANT[1]

By C. A. Jennings

The Bubbly Creek filtration plant at the Chicago Union Stock Yards requires no introduction. It has stood in a class by itself purifying probably the most polluted supply of any water purification system in the country. It was at this plant that hypochlorite of lime was first used on a practical scale for water disinfection, in the summer of 1908. Numerous articles have appeared about this plant, its operation and the wonderful results obtained. The results have been uniformly good. To many people, the results have been almost unbelievable.

The Bubbly Creek water softening plant is in its infancy and needs an introduction. At the present time the record of the filtration plant is much better than is that of the softening plant, as will be explained later. The plants are one and the same.

An agreement was entered into with the city of Chicago several years ago about the use of the filtered water from the Bubbly Creek plant. Since that time, the filtered water has not been used for watering live stock but its use has been confined to mechanical purposes. At no time, however, has the purification been discontinued, as much care is being used now to obtain a satisfactory degree of purity at all times as was used formerly.

The conditions and problems to be met with in order to soften the water with this plant were somewhat novel and peculiar to local conditions. The power house of the Union Stock Yard and Transit Company, the same company that owns the filtration plant, is nearby. The boilers there require about 125,000 gallons of water per day. Previously they have been supplied with the returns from the heating system, some 50,000 or 60,000 gallons per day, and the balance of the water was taken from the Permutit system softening city water. The Chicago Junction Railway has some 50 or 55 locomotives operating in the Stock Yards. They have been supplied with filtered water that was not softened. The amount

[1] Presented at meeting Illinois Section, January 25, 1916.

used averages about 600,000 gallons per day. Considerable filtered water has been used for flushing for a high pressure fire system and for condensing purposes.

It was decided to soften the water from Bubbly Creek and use it for the same purposes as heretofore and, in addition, in the boilers in the power house, replacing city water softened by the Permutit system.

The filtration plant was designed for 5,000,000 gallons per day with a period of coagulation and sedimentation of three hours. For several years only one chemical, alum, has been used as a coagulant. Mixture with the raw water was secured by introducing the solution into the suction of the low service centrifugal pump because the over-and-under baffles originally in the mixing canal had to be taken out as it was impossible to flush out the settled sludge from the bottom of this canal. End baffles on 18 inch centers were installed in the mixing canal in preparation for softening the water. These give a fair but not satisfactory agitation and mixing. Mechanical agitators, air agitation and a false floor in the mixing canal to reduce the depth from 20 feet to 6 or 8 feet have been considered as possible solutions for this trouble.

From an analysis of an average sample of the raw water, it should require 6.5 g. p. g. lime; 2.1 g. p. g. of soda ash and from practical experience about 1.25 g. p. g. alum in the treatment of this water. Various quantities of chemicals have been tried, starting with lime, 7 g. p. g., soda ash, 2.1 g. p. g., and alum, 1.25 g. p. g., and now with lime 9.0 g. p. g.; soda ash, 3.1 g. p. g., and iron sulphate, 1.5 g. p. g. The substitution of sulphate of iron for alum was made because the former could be used equally as well and was much cheaper. Alum was being quoted at $20 per ton, and is even considerably higher than that now, while sulphate of iron was quoted at $11 per ton. At the figures given as the present quantities of chemicals being used, the chemical cost for softening is 2.38 cents per 1000 gallons.

The water would have been uniformly softened but not to the limit, except for several reasons. As mentioned above, the plant was designed for 5,000,000 gallons per day and at that rate the settling basins have a three hour capacity. The consumption of the filtered and softened water varied from a rate of 500,000 gallons to 2,500,000 gallons per day. The clear water storage well beneath the filters has a capacity of 250,000 gallons or about 2½ hours supply at the maximum rate of pumpage. With this variable rate of

consumption, the period of coagulation and sedimentation varied from 15 hours to 6 hours. The hardness of the raw water, which receives all kinds of sewage and trade wastes, varies from 10 to 15 grains per gallon. The hardness of the softened water has varied from 5.5 to 7.0 grains per gallon as the conditions varied.

The softening process at the Bubbly Creek plant has been in operation less than two months. A number of changes have been made and the results have been bettered. It is hoped that even more can be accomplished by means of changes now being contemplated.

PRESSURE FILTERS

By Harold C. Stevens

The use of pressure filters is as old as the practice of rapid sand filtration; in fact, the first rapid sand or mechanical filter for treating a municipal supply, installed at Somerville, New Jersey, in 1885, was of the pressure type. At present, the aggregate capacity of pressure filters used for supplying potable water is not less than 265,000,000 gallons per day, which is about 13 per cent of the total capacity of all the rapid sand filters which have been installed on the North American continent. Plants range in size from very small capacities up to 21,000,000 gallons per day. The aggregate capacities of installations of various sizes are shown in the following table.

Combined capacities of pressure filter plants grouped according to size

Size of plants in millions of gallons daily capacity	Number of plants	Combined capacity in millions of gallons per day
over 20	1	21.0
10 to 20*	1	14.0
5 to 10*	9	69.0
2 to 5*	24	81.0
1 to 2*	21	33.0
0.5 to 1*	27	23.9
0.1 to 0.5	68	23.2
Totals	151	265.1

* Inclusive.

These figures do not include pressure filters used primarily for industrial service, nor those used for hotels, swimming pools, residences, etc.; there are hundreds of such installations. Some mills have filters of greater capacity than is ordinarily required for municipal service, and for the other classes individual filter capacities run as high as 1,000,000 gallons per day.

Despite their extensive use pressure filters have received but indifferent attention from sanitary engineers in general. This may per-

haps be accounted for by the lack of the structural features that always involve special design in the case of gravity filters. The unsightly appearance of the pressure filter as compared with the neatness of a gravity plant of concrete construction may also be a contributing factor. The fact that the filter bed is invisible has occasioned frequent and unduly severe criticism. The engineers of filter manufacturing companies have, however, through the years of slow development of rapid sand filtration, appreciated the value of the pressure filter as an efficient and economical device, and its practical development has been mainly due to their experience and efforts.

Extensive and careful studies of the gravity type of rapid sand filter have been made by many engineers, full records of operation have been pretty generally kept, and experience with them has been turned to good account. Much of the knowledge so gained is applicable to the pressure filter, since it is the same in principle as a positive head gravity filter. There is, however, little specific data with regard to pressure filters to aid in a close comparison with other types as to cost, efficiency and general merit.

This paucity of data is doubtless due to the small size of plants, to limited operating force, to the omission of automatic recorders and controlling devices in most cases, to technically unskilled supervision, and to the lack of incentive, which the activity of engineers could create, to systematic keeping of records. This condition is unfortunate, because there is no reason in the world why the pressure filter should not be made, by proper equipment, a thoroughly reliable and efficient means of purifying water, practically on a par with gravity filters and even superior to them under some conditions.

There are a few installations that are well equipped; a good many are operated with much care, and, so long as vigilance and intelligence are unfailingly exercised, are efficient and reliable; but most are, through lack of automatic controlling devices and through varying degrees of attention to operation, open to question as to their reliability in furnishing wholesome water at all times. Many small gravity filters are equally open to this same criticism.

Sterilization, as applied to water purification in recent years, has done much to palliate the uncertainties of filters of all types, slow sand as well as rapid sand. Nevertheless, constant efforts are still being made for the betterment of the gravity type, and why, then, should not the pressure type be equally improved? Certainly the

pressure filter cannot otherwise be brought to the high state of usefulness to which it is entitled.

The contention may be made that the pressure filter is essentially a comparatively small affair, not suitable for the treatment of large water supplies. This can hardly be admitted as sound reasoning, because in matters of public health, perfect safety is the object to be attained in all cases. Moreover, it is not true that pressure filters are unsuitable for large supplies. Atlanta, Georgia, has a plant of 21,000,000 gallons daily capacity. Filter units are most frequently of about half a million gallons daily capacity. They can readily be combined in groups, each operated by one set of devices, as many groups can be assembled in one plant as may be desired, and they can even be arranged in tiers if ground space is limited. The writer believes that pressure filters, fully equipped and carefully designed, are suitable for the largest water supplies, and that they will compare well with gravity filters as regards efficiency and cost of construction and of operation. Regarding cost, it is a significant fact that water supply companies, whose primary object is to make profits, usually adopt pressure filters in preference to gravity filters.

Standardization is one of the factors tending to keep down the cost of construction. It also favors rapid installation. The smaller sizes are actually kept in stock by filter companies, and for larger sizes designs are largely standard and many parts are stocked, so that it only requires a short time to effect the delivery of a filter of any ordinary size. The only deficiency is in the matter of refinements in controlling devices to a point of equality with gravity filters; and this will, of course, be remedied to keep pace with demand, if not in advance of it.

There does not seem to be any special difficulty in the way of applying refinements to the pressure filter, such as improved strainer systems and filter bottoms, loss of head indicators, rate and wash water controllers, and hydraulically operated gates. The question of chemical application has already been solved.

The pressure filter is essentially a positive head filter contained in a closed tank interposed in a pipe line, and provided with valves to permit reversal of flow for washing and the discharge of wash water and with a device for applying coagulant. In principle it does not differ from the positive head gravity filter, but it has a higher head of water over the sand, equal to the pressure in the pipe line, and it can be operated with a greater maximum loss of head.

The loss of head allowed is sometimes as high as 15 pounds, and is frequently 10 pounds. Probably no definite limit can be stated as generally applicable, as it undoubtedly varies with the character of the raw water, but in general it is either the point above which there begins to be danger of breaking the sediment layer through sudden changes in rate of filtration combined with excessive filtering pressure, or else it is the point above which further yield costs more on account of increased pumping pressure than is gained by lengthening the run.

Right here appears an objection to the very convenient practice of delivering water from the filter directly to the distribution system without any rate control. The filter must keep up with the demand and when an abnormally high draught occurs, as in case of fire, a very high filtering rate will result, and this sudden change, occurring at a time when the filter is about ready to wash, will be likely to cause the filter to break and deliver an impure effluent. Quite similarly it would seem that the sediment layer might be broken by pulsating pressure resulting from the action of reciprocating pumps.

Usually the only indication of the condition of the filter bed is the drop in pressure as shown by gauges on the effluent and influent mains and the appearance of the effluent. The pressure drop is a definite indication in the case of a single unit, but where the installation consists of more than one unit only the average loss of head is shown, and one unit may be badly clogged and delivering little water, while another is comparatively clean and operating at too high a rate. When rate controllers are used the loss of head gauges shows the condition of filters individually.

Pressure filters are made in two characteristic forms, horizontal and vertical, depending mainly upon the size of units, unless available space happens to be the controlling factor. Horizontal filter units, based on a filtering rate of two gallons per square foot per minute, are made for capacities ranging from 240,000 to 350,000 gallons per day; vertical filters are generally more suitable for lower capacities, ranging from 3000 to 230,000 gallons per day. Cost of construction is the principal determining feature as to form. In the horizontal filter, the sand surface is taken as the area of a plane through the axis and in the vertical filter it is the area of a plane perpendicular to the axis; so it is easy to see that for a given area of sand surface the vertical tank will be of larger diameter and will

require a disproportionate amount of metal both in the sides and heads and be correspondingly more expensive. It is not generally economical to build the vertical filters over 10 feet in diameter.

Coagulating and settling basins are in many instances not provided for pressure filters, the coagulant being injected into the influent main. All of the coagulum and sediment must therefore be deposited on the sand bed and more frequent washing would be necessary were it not for the pressure available to force the water through the filter.

Sometimes coagulating basins, consisting either of a separate closed cylinder, or of a compartment in the filter shell, are provided, but these are of small capacity as compared with the outside basins provided for gravity filters. Their value for purposes of sedimentation is only slight, but they are sometimes useful in providing a longer period, necessary with some waters, for thorough coagulation. In a number of instances coagulating and settling basins of ample size have been provided, or else existing reservoirs have been utilized as such. Settling basins are a practical necessity in treating muddy waters, but are generally omitted where comparatively clear water is to be filtered, unless a storage or distributing reservoir happens to be available. The ability of the pressure filter to handle unsettled water is one of its distinct advantages, especially where a low first cost is important.

Pressure filters have certain apparent advantages. They can be installed quickly; they are entirely above ground, and usually fit into some available space within a building; settling basins and clear well can frequently be eliminated; auxiliary pumping may often be avoided; less precision in operation is demanded, by present practice; the cost of installation is low, and the rate of filtration can be increased materially above the usually accepted rate of 2 gallons per square foot per minute. The last feature is especially important as it makes possible, without providing an excessively large nominal capacity, the practice of connecting the filter directly with the distribution system, the filter accommodating itself to the fluctuating demand without special attention.

Some of these advantages are not so real as they appear. The omission of a settling basin of ample capacity of course means a low installation cost, but the greater quantity of suspended matter which the filter alone must remove necessitates more frequent washing and correspondingly increases the percentage of filtered water

used for that purpose. The greater amount of wash water required tends in some measure to offset the saving otherwise effected by eliminating the settling basin. With very muddy water, unless the plant has an excessive filtering capacity, the clogging of the filter may be so rapid that it will be difficult to deliver a sufficient quantity of water and the loss of head may range very high, to the possible detriment of the effluent.

The elimination of low lift pumping, which the omission of a large settling basin may permit, is a definite saving in first cost, but does not materially affect the cost of operation, since the total lift of the water remains the same.

Less precise operation means an economic waste, sacrificed for the sake of convenience. It is very simple to wash a filter once a day whether it needs it or not, and provide for coagulation merely by filling the alum tank, as needed, letting the dosing device deliver a constant quantity of solution regardless of changes in the character of the raw water, but there can be no doubt that this practice results in the use of unnecessarily large amounts of wash water and alum.

The high rate of filtration that is attainable may or may not be a real advantage. So long as the effluent is not impaired, it is an advantage, but there is a limit somewhere. Above a certain point, further increase in loss of head will cost more on account of pumping pressure than it will save by the lengthening of runs and consequent reduction in wash water. There is also a critical point in the loss of head range at which the filter is likely to break, and also another point, varying with the character of the raw water, above which the filter will pass suspended matter without actually breaking. The rate of 2 gallons per square foot per minute, which has, until very recently, been credulously accepted as standard for all rapid sand filters, is really without foundation as a criterion for general practice. There are filters operating on colored, but practically clear water that cannot be made to produce a good effluent at such a high rate, and there are also filters treating turbid waters that can be operated at a much higher rate and still give perfectly good results. The success of pressure filters, with their widely varying rates and rule of thumb operation, gives evidence of the possibility of safely utilizing in many cases much higher rates than the normal rate heretofore accepted. While it is manifestly proper to take advantage of higher rates it should be done carefully and with due regard to limitations.

It must be admitted that pressure filters have shown surprisingly good results, in view of the opportunities that exist tending to inefficiency. This fact is of importance in indicating the possibilities open for improved filters.

The feature that deserves the most careful consideration is the utilization of higher rates of filtration within safe limits, making use of devices and appurtenances similar in purpose to those recognized as essential for gravity filters.

It is well known that negative head gravity filters have sometimes given trouble by passing hydrate unless operated at low rate. This substance is the neutral hydrate of aluminum, and harmless, but its presence in the effluent is considered objectionable on the sole ground of appearance. The actual quantity of hydrate of aluminum which thus passes a filter is exceedingly small, although its effect in giving the water a cloudy appearance may be marked.

This passage of hydrate appears to have been caused primarily by imperfect floc formation due to the peculiar properties of the raw water. Starting with this, the passage of hydrate through negative head filters appears to be aided by the suction effect on the underside of the sediment layer acting in conjunction with the scouring action of the water passing the filter, which detaches particles of hydrate and draws them deeper into the bed until they find lodgment at a point where the combined effect of these two forces is less. This action progresses downward as the material accumulates deeper and deeper in the bed, and as the suction head increases, until hydrate finally appears in the effluent. This phenomenon appears most frequently, if not only, with clear, colored waters, which form fragile, feathery flocs composed of very fine particles. In the treatment of turbid water the hydrate flocs are more substantial and are not drawn through the filter under the heads usually allowed in operation.

In the case of the treatment of clear waters it would appear on theoretical grounds that the passage of hydrate would not occur nearly as readily with a positive as with a negative head filter, for the reasons that the necessarily greater depth of water over the sand seemingly would tend to compact the sediment layer to an even greater degree than does induced suction from below in a negative head filter, and that there is no suction force tending to detach particles from the under side. Only the scouring effect of the water passing through the interstices of the sand remains and this, in the absence of the other

forces, may be increased, which means that a higher filtering rate may be permissible.

Here then, is a condition in which the positive head gravity filter which recovers much of the advantage it had lost to the negative head filter, although it still costs more to build and operate, because it may do effective work in cases where the negative head filter does not.

It is very likely that a general method will be devised to eliminate this apparent weakness of the negative head filter, which has been corrected in many individual cases, but the point to be made is this, the pressure filter is essentially a positive head filter, and possesses all its advantages, and moreover has a very large available working head which can be utilized to force water through a compact sediment layer and so secure reasonably large yields at the higher rate of filtration just indicated as being permissible with the positive head gravity filter.

Applying this reasoning farther, to the treatment of turbid water, it would seem that negative head filters might fail if a materially greater loss of head were applied than the customary 10 feet or so, and here again the pressure filter would have the same advantage that it has in the case of clear colored water.

One of the troubles frequently experienced with pressure filters is the necessity of adding sand to replace that lost in washing or of renewing all the sand occasionally, on account of accumulated mud within the bed. The loss of sand is plainly due to washing at too high a rate or to uneven washing. The accumulation of mud within the filter bed can only be due, if wash water is applied in the proper quantity, to imperfect distribution of wash water, just as is the case with gravity filters. Suitable wash water controlling devices and proper arrangement of the strainer system will obviate the trouble.

Only in a few instances is air used in the washing process. Surely if it is necessary for gravity filters it is equally important for pressure filters, since the conditions are exactly the same. Sometimes the interior of a pressure filter gets into a very foul smelling condition. Naturally the lack of ventilation would make odors particularly noticeable, but only an improperly washed filter would get into seriously bad condition in this respect. It would seem that the air wash should have a marked effect in preventing bad odors and that it may for this reason be especially desirable in connection with the pressure filter.

One kind of service for which the pressure filter is particularly well adapted is the treatment of water exclusively for industrial use, where the elimination of bacteria is not essential and where in some instances even complete clarification is not necessary. For this service the pressure filter in its usual form proves cheap and suitable. Good washing is of full importance, and a combined settling and coagulating basin may be a necessity in the case of a muddy water supply, but precise rate control and recording devices are not so important and direct service to the distribution system, allowing demand to control the rate of filtration, is often entirely satisfactory.

The cost of a thoroughly up-to-date installation of 1,000,000 gallons daily capacity would be about as follows:

Two 8-foot x 20-foot filters equipped in the ordinary way, including erection and foundations	$5,000
Controlling devices, air wash equipment and general improvements	1,300
Settling basin of two hours' capacity	3,500
Low-lift pumps	1,200
Superstructure	1,500
Total	$12,500

A first class gravity plant of the same capacity costs in the neighborhood of $20,000.

For large plants the cost of construction per million gallons daily capacity would be about $12,500 for gravity filters and about $9000 for pressure filters.

These figures are not offered as being exact and there will of course be considerable variation depending upon the character of the site and other conditions attending construction, and upon prices of labor and materials, but they will serve to indicate in a general way the relative cost of installation.

The cost of operation of pressure filters should be about the same as is the case with gravity filters, except that the cost of pumping may be a little greater, on account of the greater head utilized in the filter.

The cost of upkeep will be a little higher for pressure filters owing to the greater amount of steel work to be kept painted. Depreciation will also be a little more rapid, but the fact that certain pressure filters are still in use after twenty-five to thirty years of service shows this item to be almost insignificant.

The conclusions of the writer, summarized briefly, are as follows:

The pressure filter, as thus far constructed, is in some instances a very inferior means of purifying water, hygienically, and in other cases an excellent means, but on the average it is not entirely reliable.

There are no great obstacles in the way of developing it to the point of equality with the best gravity filters as regards efficiency and reliability, for any capacity and for most waters.

It is better adapted to the treatment of some waters than the gravity filter.

It is especially suited to very small water supplies and to the clarification of water for industrial uses.

The cost of construction of the highly developed pressure filter is materially less than that of the gravity filter, and low enough to more than offset a somewhat greater expense for operation and maintenance.

The improved pressure filter deserves the most careful consideration by sanitary engineers, filter manufacturers and public health officials.

DRIVEN WELL SUPPLY OF MUSCATINE, IOWA[1]

By William Molis

The water works of the city is situated on what is called Muscatine Island which is some 20 miles in area. The soil underlying is almost wholly sand and gravel, varying in depth from 20 to 60 feet. The wells are down about 50 feet, passing through top soil 3 feet, red clay 5 feet, red sand and gravel 8 feet, sand and gravel 18 feet, solid gravel down to 27 feet. Coarse sand and gravel to 42 feet, 8 feet gravel and sand with large pebbles at 51 feet, blue clay to 57 feet, soapstone clay to 59 feet, sandstone to 62 feet.

Before locating the plant on these grounds tests were made for some six months indicating the rise and fall with the Mississippi River which is some 1000 feet from the wells. The tests were made about 1 mile on each side of the location where the plant was supposed to be built. In addition a seven days test was made with a pump of about 1,000,000 gallons daily capacity throwing the water from the well into the river.

This was one of the most elaborate tests of ground water supplies ever undertaken. You will see in Hubbard and Kiersted's book on water supplies a full description of it.

Twenty inch suction pipe, 1500 feet long. Six inch wells on each side; staggered 150 feet apart. We have pumped at the rate of 6,000,000 gallons per 24 hours and only lowered the ground water 3 to 4 feet, an 8 inch casing was first driven down and then a 6 inch pipe was put on. One feature in connecting up this pipe was that the pipe was cut in place, using a Toledo pipe cutter in the trench without removing the six inch pipe.

Each well has a gate attached so it can be cut out in the line. All this work was done by the water works employees. There are also in the line tees of the full size of the suction pipe for future extension. A 20 inch gate was put in as a safety measure. A large air chamber is set on this line near the pump house, where an air pump is connected up to keep the line free from air.

[1] Presented at meeting of Iowa Section, December 3, 1915.

An air and water indicator in the pump house shows us just where the air and water are in the suction line.

The analysis of the supply shows it to be of a most excellent quality. In fact there has not been a case of disease in the city for many years which could be laid to the water supply.

The temperature of the water is about 50 degrees Fahrenheit. There are drinking fountains scattered all over the city which remain at about the same temperature the year around.

The average rainfall for this section is about 40 inches. There has been plenty of water in the seasons of least rainfall and on occasions of maximum pumpage the wells were lowered but a few feet. Other features in this work are the strainers supplying these wells. They consist of three sets of 9 slots each, cut vertically in a piece of wrought iron well casting, one set of slots were $\frac{3}{8}$ inch wide and 24 inches long, the second set $\frac{3}{8}$ inch wide and 21 inches long, and the third set $\frac{1}{4}$ inch wide and 33 inches long, each set being separated by 8 or 10 inches of solid metal. The length of the strainer is about 8 feet. The area of openings about 220 square inches or about 4 times the area of the 6 inch pipe. The bottom of the pipe was plugged, and each well was pumped until there was no visible sand coming up. Such strainers should be used with caution. If there is coarse gravel they will work well but should there be fine sand, it is liable to work into the slots and give a great deal of trouble by the fine material coming in and cutting out the pumps.

FURTHER DEVELOPMENT OF IRON REMOVAL PLANT AND STORAGE

By F. C. Amsbary

In the year 1913, the Champaign and Urbana Water Company installed a gravity filter plant for the purpose of removing the iron content from the well water with which it supplies the twin cities. The iron is present in the raw well water to the extent of about two parts per million.

Papers have been read before this association describing the plant, the methods of operation and some of the difficulties encountered in getting the plant to operate successfully and continuously.

You will recall that considerable difficulty was experienced before efficiency was obtained, the greater difficulty being the fouling of the sand beds due to the tenacious nature of the iron oxide collected on them.

It had been the custom at our plant to use a fire hose on the surface of the filters whenever they became so clogged that they would not last through a fifteen hour run with any degree of efficiency. This seemed to tear the floc loose and clean up the sand bed so that the filters could be used for several weeks again when the same operation had to be repeated.

The benefits resulting from the use of a fire hose upon the filter bed demonstrated the possible applicability of a high pressure wash regularly applied to the top of the bed. Suggestion was made by Mr. W. W. DeBerard during the meeting of this Society in May, 1915, of a high pressure grid placed a few inches above the sand bed while the latter was at rest but which would be submerged in sand when the wash water was applied to the under drains. This method had been tried out at Oakland and found to work in a very efficient manner. Accordingly, during July of 1914 an experimental grid was placed in one of the filters. After six months' trial the effectiveness of this grid was so evident that similar grids were placed in all of the filters.

The grid system as installed for experimental purposes consisted of two parallel manifolds made up of 4-inch nipples, 15 inches long, and 4 x $\frac{3}{4}$ inch crosses. Lengths of ordinary $\frac{3}{4}$ inch galvanized iron pipe, $2\frac{3}{4}$ feet long, capped at the outer end, were screwed into the crosses thus forming the laterals to the grid system. The laterals were perforated on their under surface at 12 inch intervals with $\frac{1}{16}$ inch holes. Perforations were found to clog rapidly so the size of the holes was enlarged to $\frac{1}{8}$ inch and finally to $\frac{3}{16}$ inch.

A fairly even distribution of the wash water is secured. There is approximately one perforation per square foot of filter area. The discharge through the grids is estimated at one-third the discharge through the under drains.

Since all of the grids have been installed at least six months, it can be stated more or less definitely just what has been the advantage of this installation. The quantity of wash water required to wash the filters has been reduced more than one-third. Approximately 25,000 gallons per filter per day are now required where formerly 35,000 gallons per filter per day were required. As to the frequency of washing, when it is necessary the filters can be put through a 24 hour run and still maintain a fair degree of efficiency. Formerly at the end of an 18 hours' run the sand bed would be almost impervious.

Frequent analyses of the effluent show an average iron removal of 95 per cent, the product being very satisfactory to the patrons.

And now comes a chapter in the story of the efforts to improve the quality of the water supply that has given much concern. We were congratulating ourselves on finally succeeding in removing the iron when we began to get complaints from our customers that small red worms had been found in the water. At first we thought this an error, but when a customer brought to our office a bottle of water containing perhaps a dozen live squirming red worms, we immediately began an investigation.

The bottle containing the worms was taken to Dr. Forbes, state entomologist, who immediately classified them as larvae. He assured us they were entirely harmless, in fact when found in water supplies it indicated the water to be of high purity. We were of course considerably relieved and the next customer that complained was assured that he should not be alarmed that we had the authority of Dr. Forbes that they were harmless and their presence in the water proved it of an unusual purity. But he said, "Dr. Forbes and

you be darned. If you expect me to buy water full of worms and *pay* for it, I will refer the matter to the mayor and city council, the State Public Utilities Commission, the board of health and the pound-master."

Several other interviews with irate, worm-hating customers convinced us something would have to be done, somehow Champaign and Urbana water consumers could not reconcile pure water with a worm content. Though in discussing the matter with our patrons we used the word larvae, the word seemed more refined, less vulgar, in every case the patron used the word worm. In fact one man man was impolite enough to call them small snakes.

Somewhat discouraged we again called on Dr. Forbes and asked him what could be done to be rid of the pests. It was suggested that fish or frogs be put into the reservoir, that they would feed upon the larvae and a system of screens could be installed to prevent the fish or frogs from finding their way into the water pitchers about town.

This did not appeal to us, for we did not care to turn our reservoirs into fish or frog ponds. Dr. Forbes informed us that a period of six weeks was necessary for the evolution of the eggs to the winged midge. We then decided to clean our filtered water basin once a month and break up the breeding ground of the larvae.

Dr. Forbes was asked to write an article for the paper explaining the matter from a scientific standpoint which would tend to allay the fears of our patrons, who were already blaming us for all the sickness in town, until we had time to carry out our plans.

This he did. Dr. Forbes' article on this subject published in the *Urbana Courier* was as follows:

Dr. Forbes Describes the Larvae

Nearly every one must have noticed in spring and fall, swarms of small midges stationary in the air at a little distance above the ground, especially in the neighborhood of ponds or water courses, every member of the company flying actively around and about and in and out, but the swarm as a whole curiously motionless or perhaps rising and falling slowly with the wind. These little midges, often called harlequin flies in England, are really executing an intricate aerial dance, each swarm being a dancing party of males, into which an excited female will every once in a while make a sudden dash, seizing upon an unreluctant male and flying away with him for a mate. Later she dips down to the surface of the stream or pool and lays a rope of delicate eggs held together in strings by a gelatinous envelope which immediately swells

up when wet into an abundant, transparent mucilage, within which the eggs are held imbedded.

From these transparent larvae presently hatch, and sink to the bottom, where they lie buried in the mud and sediment, feeding on particles of vegetation and other organic debris which it contains. They are so abundant in our natural waters that they are an important element in the food of nearly all our fishes, and I have myself taken them in quantity from the stomachs of black bass, white bass, perch, sunfish, crapple, minnows, suckers, buffalo fish, dogfish, spoonbills, etc., more than sixty species of Illinois fishes in all which I know to feed upon them. We have immense collections of these little larvae from all kinds of Illinois waters; and a specialist has been at work for months at my laboratory unraveling their classification, describing new species, rearing larvae to the winged midge, and helping to make us acquainted with this important complex group. Some kinds of these larvae are colorless and nearly transparent, others are white, and a good many are red, from which fact they have received the common name of "blood worms." They are not worms, however, but insect larvae, as I have just explained.

They are entirely harmless in every stage, the larvae helping to keep the water clean by devouring substances which might otherwise decay, and the midges, notwithstanding their mosquito-like appearance, being unable as well as indisposed to bite. They become troublesome only to those who do not understand their nature when they appear in our water supply, as they sometimes do, whether this comes from springs or other superficial sources, or is exposed to the air for a time in an open reservoir. They are occasionally seen in the Urbana tapwater, although so rarely that I have never seen them there myself and I am writing this note merely to assure the people of the town that they are not in the least injurious or dangerous and that their occasional appearance here means nothing at all except that the female harlequinfly has deposited some eggs in the water works reservoir. Mr. Malloch, of my staff, has reared and identified our water works larva, and finds it identical with a widespread species occurring abundantly in waters of various descriptions in nearly all parts of the state.

(Signed) STEPHEN A. FORBES,
State Entomologist.

To clean the filtered water basin it was found necessary to pump unfiltered water into town for a couple of days, so we built another filtered water basin and connected the two together with an 18 inch pipe and so arranging the pipe connections that we are able to deliver filtered water into either one or both. Also, we laid a new 18 inch suction line by—passing either basin so that with the present arrangement, we can clean either basin without interfering with the service.

This new basin was completed in July and we have cleaned the basins a number of times and each time finding fewer of the larvae present in the basins. We feel that we have broken up the larvae nest. The last time the basins were cleaned no signs of larvae could be found.

DISCUSSION

Mr. W. D. Gerber: Mr. Amsbary's paper brings out very forcibly again the fact that here at the state university we have men of special training, experts in their respective lines, who are ready and anxious to assist in the solving of any unusual problem. While we have all left our student days behind, still we are each day working along on our post graduate work, and when we find a problem that is out of the ordinary we should realize that the university is still our instructor and turn to her at once for help. Some of us have learned to take advantage of these resources of the university, but it is to be regretted that more of us have not done so, and until we all do we are denying her the opportunity to supply the great service for which she was created.

SUCCESSFUL WATER SOFTENING AND WHAT IT COSTS THE VILLAGE OF HINSDALE[1]

By C. B. Williams

Certain cities of the country have solicited and obtained aid from engineers and managers in correcting their water troubles, often called the red water plague; but many towns and cities are afflicted with what might be called the hard red water plague. This is especially true in parts of Illinois, and these cities, except for a more or less internal grumbling, remain inactive.

Why any prosperous community will for years put up with a water supply which is universally condemned is a psychological question that has never been satisfactorily answered. The same poor service from some other public utility would bring such a storm of disapproval that it would shortly be corrected.

Hinsdale, Illinois, was in this rut. It is a rapidly growing suburb of Chicago of about three thousand inhabitants. The village owns and operates a water and light plant and garbage incinerator.

The water supplied to the village is from a 12 inch well about 210 feet deep, the supply coming from the limerock known as the Niagara limestone. This water, while entirely unaffected by any surface contamination, is very disagreeable on account of its extreme hardness, its strong taste and its excessive iron contents. The latter forms a deposit in the pipes, which when disturbed by an unusual consumption, as in the case of fire, or the shutting off of a district for repairs, causes the water to run red for a number of hours thereafter.

General dissatisfaction with this supply led the Hinsdale authorities to investigate the softening process, and to its final adoption. Last August the village put in operation a softening plant of about 1,000,000 gallons daily capacity, using the standard lime and soda ash process.

The old plant consisted of steam pumps, pumping directly from the well to the mains. The addition of a primary pumping unit

[1] Presented at meeting of Illinois Section, January 25, 1916.

and a softening plant made necessary the rearrangement of the steam pumps and the piping, but left them available for the final pumping.

The water is now lifted from the well by an electrically driven centrifugal pump, against a total head of 90 to 95 feet, to the top of a softening and settling tank. On entering the tank the raw water is dosed with the lime and soda ash solution. The treated water is directed downward in this tank by an interior cone to within a few feet of the bottom, thence it rises slowly allowing the precipitate to settle to the bottom. This precipitated sludge is removed daily from the tank by a revolving sludge remover and is discharged directly into the sewer.

The settled water is drawn off at the top of the softening tank either to the storage tank of 250,000 gallons capacity or directly to the filters. The filters are of the rapid gravity type, built over a clear well of 12,000 gallons capacity from which the steam pumps take their suction.

Over the filter and clear well is a two story brick house, the second story of which is used for chemical storage. In the lower room with the filters are the chemical mixing tanks, pumps and proportioning apparatus for feeding the chemicals.

The treated and filtered water is clear, bright and free from iron, and as operated the hardness is kept between four and five grains per gallon of hardening salts.

The following analyses of the raw, settled and filtered water were made by the Illinois State Water Survey on October 7, 1915.

Parts per million

	RAW	SETTLED	FILTERED
Turpidity	15	30	0
Color	5	15	0
Alkalinity	362	98	92
Sodium nitrate	1	1.6	0
Sodium chloride	2	2	2
Sodium sulphate	118	263	257
Sodium carbonate		47	43
Magnesium sulphate	120		
Magnesium hydroxide		8	8
Magnesium carbonate	20	17	13
Calcium carbonate	338	16	16
Iron carbonate	3		
Undetermined	42	62	31

A test of thirty days duration has been run to determine the cost of chemicals and the amount of water used for various purposes, which gave these results.

Total water softened	10,016,130 gallons	
Total water used by consumers	8,785,208 gallons	
Total water used in boilers	759,983 gallons	
Total water used washing filters	156,457 gallons	1.56 per cent
Total water used for sludging	216,895 gallons	2.16 per cent
Lime used per thousand gallons	4.001 pounds	
Soda ash used per thousand gallons	1.368 pounds	
Alum used per thousand gallons	0.28 pounds	

The cost of lime is 0.37 cent, soda ash 0.795 cent and alum 2 cents per pound, at these prices the cost for chemicals is 2.624 cents per thousand gallons. To this chemical cost must be added the cost of power used for the primary pumping, which is 1.35 cent per thousand gallons; the cost for attendance is small, as only part of one man's time can be charged to softening or 0.4 cents; interest, depreciation and repairs bring the total extra cost to 5.917 cents per thousand gallons. This is the extra charge that the village must meet to obtain soft water.

To show concretely the actual saving to the consumers for this extra expense is rather difficult. In Hinsdale the great majority of the 800 consumers have rainwater cisterns, and the houses are double piped and provided with electric or water motors for elevating the soft water. This costs each householder an investment of $300 to $500.

During this year at least thirty houses have been built in which this investment has been saved. The interest, depreciation and repairs on the $300 minimum investment amount to $28 per year, and are entirely saved in the new houses; while on the older houses there is at least a yearly saving of $7.

The use of bottled water by many who disliked the old water has been nearly discontinued; several laundries make large savings of soap, and boiler users save considerable sums formerly spent for boiler compounds and repairs.

It is evident that could all the various economies be as definitely shown as is the cost of softening, there would be an appreciable credit to the softening process. Further there is a certain satisfaction and value to having available any quantity of soft, drinkable and perfectly clear water not measurable in dollars and cents.

The people are the final arbiters of the success or failure of an engineering project, and it is safe to say that the residents of Hinsdale would pay many times the cost of the plant rather than return to the old unsoftened water. To quote one prominent citizen—

I was very much opposed to the project from its inception and did all in my power to defeat it, but I will say now, that if for any reason the plant should be discontinued, I would leave Hinsdale at once.

EROSION OF WATERSHEDS AND ITS PREVENTION

By Benjamin Brooks[1]

The problem of soil conservation on a watershed is like the problems of flood prevention, navigation and power development on a river. To be properly solved it must be studied broadly from the source down. Much more popular interest and support and much better results have been obtained by handling river navigation, flood prevention and power development together than by handling them separately, for they are all three related. But erosion of watersheds is first cousin to them all, and should be included in the discussion of the family affairs. It should be put on the list of natural resources to be conserved, for upon it we chiefly depend for our 300,000,000 square meals a day.

United States Army engineers have spent a great deal of money dredging harbors, removing sand bars and setting beacons for the sake of navigation. The mud they dug was of no interest to them. Other engineers have spent other large sums in chaperoning unruly rivers across the map so that they could successfully carry their silt along to fill up the harbors again. To them the mud was merely a menace to fill up their channels during low stages of the river so as to cause it to seek new channels during freshets.

In 1840 the Chemung River in New York appeared to an engineer who was born upon its banks, and was then six years old, as a clear, smooth stream with well-defined channel and firm grassy banks. Fifty years after, at the time of a freshet, it was scarcely recognizable. The banks were twice as far apart, the river was full of bars and had forsaken its proper course to tear up the crops and the property of the unhappy citizens who lived beside it. This old inhabitant blamed the wood cutters for this, without measuring the stream to find that no more water was going by than in his childhood and without stopping to consider that accurate gaugings for fifty years, on American rivers and for eight hundred years on the Danube show no general increase in floods throughout the whole process of

[1] Read at meeting of Illinois Section, January 25, 1916.

deforestation and civilization, that is, no general increase in the *amount* of water carried during floods, although the destructive effect of this amount has increased many fold. Why?

Very few engineers have followed this question properly to its source, nor regarded it as a sufficiently close relative to our other river questions, to solve it. One reason for this is that, as we approach the source of the difficulty, the problem frays out into countless separate little problems too small to interest the civil engineer or to pay him to solve. In fact, among older peoples, the solution is already well known. The chief difficulty in our new civilization is to get the old solutions applied. In the mountainous districts of the Philippine Islands, for instance, the savages, so called, although they have not yet discovered how to wear breeches, have developed a tremendous system of retaining walls and terraces so that entire flanks of the steepest mountains that would lie bare to the cloudburst and deluge in our states are brought under intensive cultivation despite a customary and frequent downpour of two feet of rain a day. In the Caucasus Mountains the inhabitants often use a similar system, and so well aware have they become of the value of soil that, if any escapes them, they descend to the valleys and carry it painstakingly back again in baskets on their heads.

In the uplands of the Carolinas and Georgia the farmers have been in business in one place long enough to realize that the light top soil which floats away from them so easily is their principal stock in trade and must be conserved. Through this district there is scarcely a hillside that is not completely terraced, the steps being maintained by stiff, thick, lowcut hedges which are not interfered with during cultivation. In this same district the Mangum terrace was invented, a low mound approximately following the contour, able to retail soil and prevent stream flow, but still allowing the agricultural machinery to pass over it. The inventor's detailed specifications for this kind of terrace are as follows:

Specifications

1. With transit, or farm level, lay out lines having a slope of about $1\frac{1}{2}$ inches in 14 feet. On very washy soils lessen this slope; on rather tenacious ones it may be slightly increased.

2. Space these lines at intervals of about 6 feet of fall, marking their courses with stakes or shallow furrows. They may thus come twenty paces apart, on steep land, or seventy-five or more on gentle declines.

3. With a two horse plow follow these lines, throw the furrows up hill below the line and down hill above it, so that the back furrow and the terrace line correspond in each case.

4. When a rain has settled the ground, repeat this process, or, better yet, use a drag scraper or shovels to throw the soil from the upper to the lower side of the terrace.

Thus the terrace is built, but it must be carefully watched for a few years and built up or smoothed over as conditions require, until it becomes permanent.

Coming now to a newer country nearer home, we can see the idea of soil conservation just beginning to take root. The writer has met and talked with some of the oldest farmer inhabitants along the south bank of the Missouri. Their farms lie in a hill country with very light soil some miles back from the main stream, but drained by small tributaries. These men have been through the whole gamut of experience, starting with smooth, grass covered farms, plowing the grass under, loosening the soil and having it wash away from them, leaving only deep ragged gullies and mortgages; then having to devise their own means of retaining what soil was left and refilling the gullies with it.

To accomplish this they worked on two main principles of soil conservation, which they discovered slowly but by bitter experience. They found out what every civil engineer knows, that running water caught in the act of robbing a farm of its soil, can be arrested in a pool long enough to drop its loot and go on *empty handed.* Their method of arresting it is simply to throw earth dams at intervals across the gullies; but, in order that the dams shall not be overflowed and washed out, they provided each one with a bypass pipe underneath and a suitable riser made of ordinary clay sewer pipe, so that the water pooled and rose to the height of the bypass, dropped its soil, and ran off comparatively clear. As the gully filled up with this deposited soil, they raised the dam and added more sewer pipe to the riser until the entire gully became a flight of smooth terraces instead of a hole in the ground.

The other principle they discovered is also well known to us, the fact that water, soaking slowly down through soil and out through subdrains, will cause no erosion; while the same amount of water coursing over the surface will cause it. Accordingly, some of them laid clay drain tile along the bottoms of the gullies and filled in over them. Sometimes they combined the two ideas, throwing

low dams across the filled gullies and connecting a riser pipe with the drain below. They went so far as to get the county supervisors to allow them to take out their old wooden culverts which let soil and water alike go by, and to put in soil saving sewer pipes wherever a bad gully crossed a country road.

But these successful farmers are but a very few out of many. Everywhere one travels in the Mississippi Valley, by simply looking out of the car window in any county in any state, one sees innumerable places where farmers have tried to prevent this soil erosion by filling their gullies with tin cans, brush and unprotected mud dams. None of these crude attempts works. The soil keeps going.

Now here is the important and most regrettable point. Although these petty details on the farm can never each receive the individual attention of a life-sized engineer, still it is exactly from these innumerable small beginnings that the ruination of the continent—already said to have spread over three million square miles—begins. These are the little sources from which rivers receive the silt that lessens their depth, increases their width, spills their floods over valuable property and shoals the harbors. The source of the soil is not the source of the main rivers. The Missouri, the Platte, the Arkansas, the Red River are all comparatively clear streams near their sources, and receive their load of soil only when they reach plowed land. Old farmers have shown me tributary streams which used to be clear before they broke the soil, but which are now heavy with brown silt. There are old charts of San Francisco Bay and the testimony of old time yachtsmen still living to show that certain towns near the confluence of the two principal rivers of the state were once on navigable water although it is now impossible to get within a mile of them in a boat drawing three feet. This change is coincident with the cultivation of the broad valleys above. When the Phoenicians first landed at the eastern end of the Mediterranean they founded their cities on isolated rocks off shore. When the Israelities came to cultivate and plow the adjacent slopes, these cities became part of the mainland. Government reports, engineering reports, history and geography all contain copious proofs that agriculture is the chief factor in soil erosion, river clogging, flood increase and harbor shoaling.

But it will be a long time in this country before farmers generally will be driven by necessity to conserve their soil for its own sake. They will never do it for these other considerations of flood pre-

vention and navigation. We engineers will never have time to devote to each farm piecemeal. The matter must be handled in a more wholesale, inter-related way; and the object of this paper is principally to suggest two or three ways.

The United States government is already on the point of saying how much sewage a community may dump into a river on account of public health. Countless analyses have already been made along our principal streams in preparation for saying just this. Is it inconceivable that once having demonstrated to the right authorities where the soil comes from, the government, instead of appropriating millions of dollars to fix up temporarily a silt clogged river, might take account of the silt content in a certain tributary stream and compel every farmer on its water shed to take such precaution against soil erosion as to prevent it, or pay a fine for spoiling the public's navigable river.

Or take it in connection with floods. We all know that tile draining is something more than a quick way of shedding water. It will take the farmer, generally speaking, a long, long time to think of it as a means of improving his soil, of emptying it of surplus water and filling it with air without drying it, to his great benefit. But if we were to regard tile drainage on a large scale throughout wet lands as a means of making the entire floor of the Mississippi Valley into a storage reservoir three or four feet deep which could have no surface torrents rushing over it, but which would deliver water to the rivers at, say, half an inch each 24 hours, then the flood prevention commissioners might take notice and ultimately find a way to penalize a man who neglectfully stored a potential flood on his land. By such a stroke all three difficulties, soil erosion, navigation interruption and floods, could be overcome at once and on a large scale compatible with modern engineering.

Or take it again on the principle of public sanitation. While our American health boards and investigators have been studying various bugs, flies, germs and fungi to discover which is the cause of pellagra, that European scourge that is gaining so rapidly in this country, the University of Rome, after years of continued research, has definitely determined and proved that pellagra is caused by muddy water, by the erosion of agricultural soils containing colloidal silica. In New Hampshire, Nevada, Utah, Wyoming, and Minnesota districts free from clay muddied waters there is no pellagra. In the Carolinas, in Georgia, Missouri, Illinois, places

where the farmer turns the streams a rich chocolate color, there is an ever increasing and seriously menacing amount of it. To prevent soil erosion would eliminate one more hitherto invincible enemy of mankind.

The American farmer, no matter how little he reads or how heedless he may be of our individual suggestions, will finally come, through dire necessity, to the idea of conserving his soil just as the naked farmer of the Philippines has finally left off hunting the heads of his wife's relatives and taken to giant powder, rock drills, stone walls and terraces; but if our influential engineering societies can suggest strongly enough to our influential law makers how the important problem of soil saving may be connected to and handled with our other great national engineering problems, we may save a few generations of time and a great part of the arable continent.

IMPROVEMENTS TO THE WATER SUPPLY OF ST. JOHN'S, NEWFOUNDLAND[1]

By F. F. Longley

The City of St. John's, Newfoundland, has for some years past been troubled with deficient quantity and pressure in its water supply, and asked advice about a year and a half ago as to the situation and suitable remedies.

St. John's has taken its water supply for many years past from Windsor Lake, some four or five miles west of the city. This lake lies at an elevation of about 500 feet above sea level. Its capacity is large and it has always been, and is still adequate for the needs of the city. The watershed is almost without habitation, and the quality of the water, without any treatment, is therefore excellent. From the easterly end of the lake a conduit extends about two miles to a basin. From this basin two pipe lines, mainly 16 inches in diameter, extend to the city by two different routes.

The most obvious defect in the entire system was the inadequacy of the distributing mains in the city. The accompanying diagram shows in full lines the larger mains of the distribution system as it then was, and in broken lines the mains that were recommended to improve the conditions of distribution. The consumption of water in the city averages about five million imperial gallons a day. It will be noted at once that for a city of this size and with this consumption of water, the system is extremely weak in large mains. This naturally resulted in a great loss in pressure, especially when the consumption rose towards its maximum.

Winter conditions have always imposed a severe drain on the water supply, as the construction of the houses and the design of the plumbing and the methods of heating in common use do not tend to prevent the freezing of the pipes within the houses, and the water is quite commonly permitted to run to prevent freezing. The cold weather draft of water, therefore, runs up very high and at these

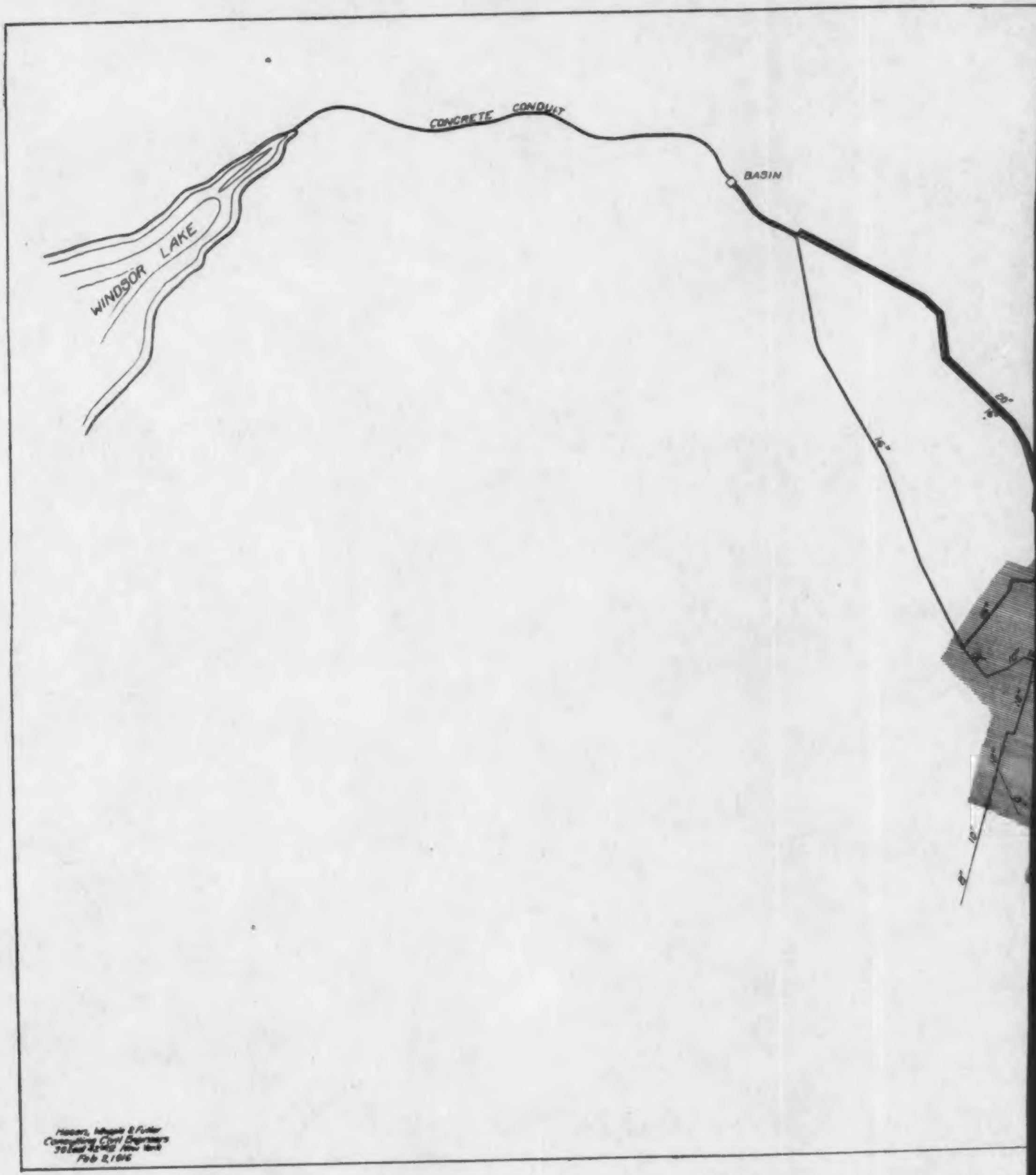
[1] Presented at New York Section of the American Water Works Association, February 16, 1916.

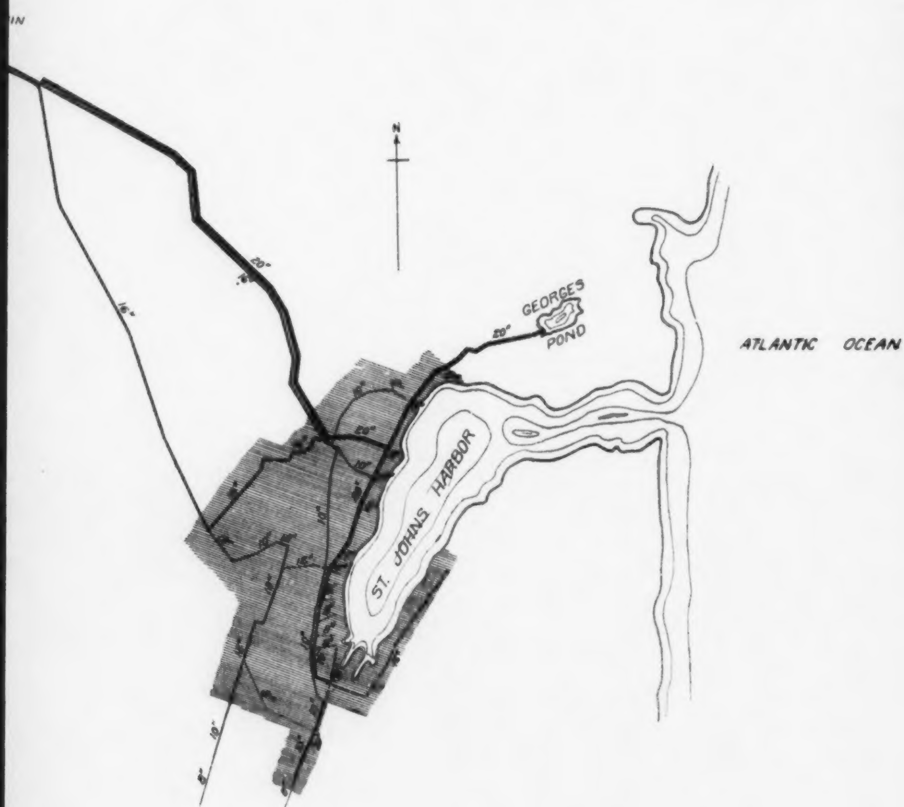
times the pressure in the city has at certain times and certain places almost disappeared. Besides the reduction of waste, the thing that was obviously needed was a few main arteries which would carry the quantity of water demanded by the city to the most remote parts with a minimum loss of head. The diagram shows the location and extent of these additions. The work of laying these new mains went forward during the past summer and at the end of the working season most of the mains lying in the city had been laid and were ready to put in service.

A series of tests were at that time made upon the improved system. The first was a leakage test. Some 8000 feet of 20 inch and 16 inch mains were tested under approximately the normal working pressure, and found to give a leakage not exceeding about two gallons per minute, indicating that the work had been well done. Then fire stream tests were made, to show the improvement secured by the addition of these mains in the pressures over the lower part of the city. A quantity of hose and play pipes were borrowed from the fire department and streams taken from a number of hydrants along the busy part of the principal business streets, the streams discharging into the harbor. The maximum number of fire streams thus taken was eleven. Pressures were observed at a convenient hydrant from which no fire stream was being drawn.

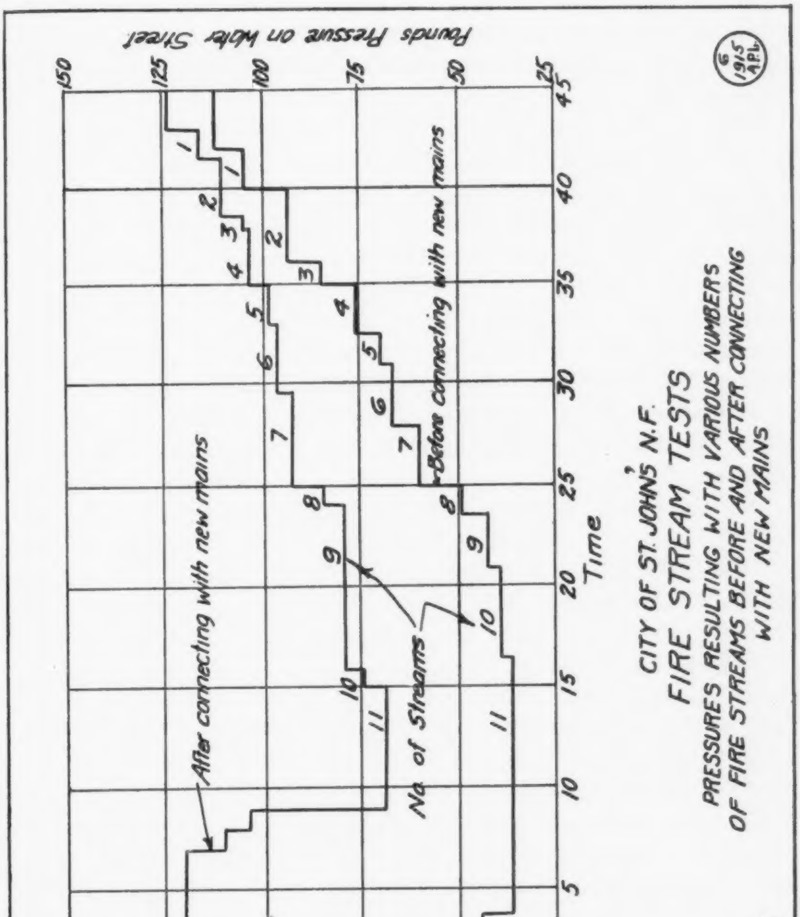
As the system stood before the new mains were connected with the old ones, the pressure along Water Street was drawn down by these eleven fire streams to about 36 pounds. It is proper to note that the regular consumption at this time was moderate, and therefore the prevailing pressures about as good as could ever be secured in recent years. One fire stream after another was then shut off and the resulting pressures noted as the draft diminished until finally all of them were shut off. The results of this procedure are shown graphically on the diagram. After the new mains had been connected to the old ones, this procedure was repeated. The pressure in this case, with eleven fire streams being drawn, was reduced only to 68 pounds, and the successive increases in pressure resulting from the diminishing number of fire streams as they were successively cut off is again shown on the diagram.

The presence of the new mains, therefore, increased the fire service in this part of the city approximately as follows: The pressure which yielded four fire streams in the old system now yields ten streams; the pressure which yielded three fire streams in the


CONCRETE CONDUIT
WINDSOR LAKE
BASIN
20"
16"
Hazen, Whipple & Fuller
Consulting Civil Engineers
Feb 2, 1916



CITY OF ST JOHNS N.F.
IMPROVEMENTS TO WATER SUPPLY
DIAGRAM OF PRINCIPAL MAINS


CITY OF ST. JOHN'S N.F.
FIRE STREAM TESTS
PRESSURES RESULTING WITH VARIOUS NUMBERS OF FIRE STREAMS BEFORE AND AFTER CONNECTING WITH NEW MAINS
Pounds Pressure on Water Street
Time
After connecting with new mains
Before connecting with new mains
No. of Streams

old system now yields eight; the pressure which yielded two fire streams in the old system now yields six.

Similar tests were not made in other parts of the city, but the arrangement of the new main arteries is such, that substantially similar results may confidently be expected in any part of the business district.

It should be noted, too, that all the benefits of the improvements are not yet secured. Those above mentioned are the result only of strengthening the distribution system within the city. Certain added benefits will follow the laying of the additional supply main from the source, and the connection with the new service reservoir.

The old water main in Water Street, the principal business street, is only 6 inches in diameter, totally inadequate in itself to serve the requirements of such a street. This street is paved and it was desirable, therefore, to lay the new main on a nearby parallel street that was not paved. In order to give to this small Water Street main the full benefit of the increased pressure in the new mains, a number of short connections were made 8 inches in diameter between the new 20 inch main feeder and the old 6 inch.

The new mains include also a 12 inch, running from the 20 inch up the hill in the western part of the city, to connect with the old 12 inch that leads from the westerly 16 inch supply line. Also a 12 inch around to the side of the harbor opposite the city, to afford fire protection to the docks and warehouses there. Also numerous extensions and replacements of smaller mains. The improved system will afford the city a much better distribution of pressures than it has had for many years past.

The intake of the system at Windsor Lake is quite inadequate. One of the most serious intake difficulties is with ice. In order to eliminate these difficulties and to provide means for maintaining an adequate supply under all conditions, plans have been made for a new intake of 36 inch steel pipe extending some 600 feet more or less into the lake.

In the past, the city has had no means of measuring the quantity of water used. Some measurements were made for the first time in the Fall of 1914, by means of a weir, but it is not convenient to get a continuous record by such a method. Plans have therefore been made for Venturi meter, gate house and connections which will afford complete means for the measurement and control of the flow.

St. John's has had no service reservoir in the past, depending upon

the flow through the long supply lines to take care of the maximum as well as the ordinary draft. A natural lake known as George's Pond lies in an admirable location and at a most suitable elevation for a service reservoir. George's Pond has an area of about thirteen acres and a good depth. It lies at an elevation slightly higher than 300 feet above sea level and at a distance of only a few thousand feet from the eastern end of the city. Its drainage area, which is small, lies on the high ground immediately overlooking the sea to the east of the city, and this area is devoid of human habitation. The elevation of the pond is such as to give good pressure for domestic and fire service along the water front and for a considerable distance back into the city, and it gives hydraulic conditions that fit in well with the elevation of the main supply.

A 20 inch pipe is being laid to this pond from the mains in the city, thus affording an economical arrangement for a large reserve supply close to the city and securing also a considerable saving in the capacity required in the main supply lines to take care of the maximum demand.

The weir measurements that were made when this study was first taken up indicated that during that period of a week the average rate at which the water flowed to the city was 5.3 million imperial gallons per day, representing a per capita consumption of about 166 imperial gallons per day, based upon the population connected with the distribution system. The measurements indicated further that the maximum rate at which the water was drawn throughout the twenty-four hours during the week of test was 5.8 million and the minimum rate 4.7 million imperial gallons per day, the minimum being over 80 per cent of the maximum. This minimum flow did not represent a compensating flow to a reservoir or anything of that sort, but clearly indicated a large waste throughout the twenty-four hours. There are but few manufacturing or commercial establishments that consume any considerable quantities of water regularly at night and it is, therefore, probable that the waste is constantly going on day and night at a rate somewhat approaching the observed night rate of flow.

One of the points of most importance to the city, therefore, was the detection and elimination of this waste. The practice of wasting water through house fixtures in the wintertime to prevent freezing is common and is freely admitted on all sides, and unfortunately this practice is not confined to the houses of the poorer class. The

effect of this winter waste is to lower the water pressures all over the city, sometimes to the point of disappearance in certain sections. Entirely apart from the winter waste, there is the continual waste mentioned above, which is roughly indicated by the night rate of flow. Much of this large amount of waste could be detected and eliminated if the problem were properly attacked. The most effective way of getting at this would be by the use of meters. This was recommended and it is to be hoped that the city will adopt the recommendation.

From the magnitude of the waste, it appeared that something might be done rather rapidly to indicate where the loss mainly occurred, by means of a subsurface study of the distribution system. Therefore various parts of the distribution system were isolated and a rough measurement of the night flow into such districts made, assuming this night flow to represent approximately the leakage therein. Suitable equipment for convenient and accurate measurement was not at hand and it was therefore necessary to improvise a method with the material available. This was done at first by simply connecting a hydrant within the isolated district to one outside, through a fire hose of known length and diameter, and measuring the drop in pressure between the two hydrants, making proper corrections for differences in elevation. The quantity flowing was then roughly estimated from the friction loss through this hose. This obviously was a preliminary step only, but it resulted in showing in what districts to look for large waste, and a rough approximation of the quantity of leakage therein.

Later, a meter was inserted in the hose line. Careful observation of the meter gave indications of changes in the rate of flow and this method was used to follow up the first method. The isolated district was then reduced in size by successively closing all available gates, while the meter was under continual observation, and this resulted in a much closer localization of the waste.

From these rather rough methods it was made clear that from 75 to 80 per cent of the total night flow in the districts examined was on the house services and only 20 to 25 per cent on the mains. This, of course, was followed up as vigorously as possible by a house to house inspection and produced results which have encouraged the city to plan further and more thorough work along similar lines.

Owing to the fact that the available force has been busily engaged during the past year on construction work, the matter of waste

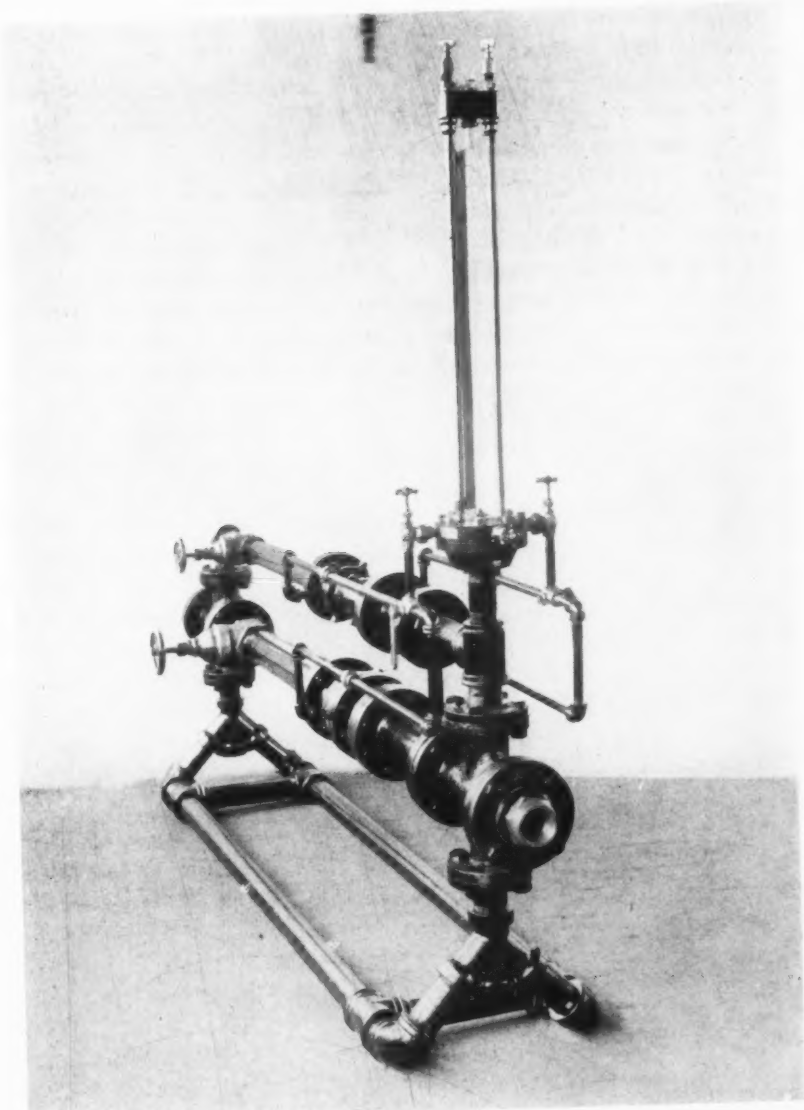


FIG. 3. WASTE DETECTING APPARATUS

reduction has not been followed up as actively as might have been wished, but it is to be followed up when conditions permit. An apparatus for use in connection with this work has been secured and a picture of it is shown herewith. It consists, as will readily be seen, of two small Venturi meter tubes, one 3 inch x $1\frac{1}{2}$ inch, the other 2 inch x $\frac{5}{8}$ inch, erected on the same stand and connected by suitable pressure pipes and valves to a manometer with two scales, one for each of the meter tubes. By means of this apparatus inserted in the hose line connecting two hydrants, one within and one outside of the isolated district, very small changes in rate of flow into the district may be observed, yielding information which will permit the elimination of even small amounts of waste on the various services. This equipment was tried out in St. John's two or three months ago and found to work with excellent satisfaction.

WATER SOFTENING BY FILTRATION THROUGH ARTIFICIAL ZEOLITE[1]

By Daniel D. Jackson

As rain falls to the ground, it is, of course, soft water, but as it comes in contact with the earth's surface and particularly if it percolates through the soil, it becomes hardened by dissolving compounds of lime and magnesia. The extent of this hardening depends upon the nature of the soil and the time of contact.

These salts of lime and magnesia are detrimental to many manufacturing processes; produce scale and corrosion in boilers, and render the water less suitable for drinking and general domestic use.

The method which has been most extensively used for softening water is that of treatment in large tanks with solutions of caustic lime and soda ash. The lime and soda precipitate the greater part of the hardening compounds in the water which settle to the bottom of the tanks and are from time to time drawn off and disposed of. This process involves the use of tanks which take up a considerable amount of space; the more or less constant attention of a man for the feeding and regulation of chemicals, and the necessity of the disposal of considerable amounts of sludge.

These difficulties are done away with in the new process, which involves the simple filtration of the hard water through a bed of artificial zeolite. The discovery of this new process was made by Prof. Robert Gans, Director of Chemistry of the German Geological Survey. It was through an investigation of the bodies in the soil and their properties which are utilized for the purpose of fertilization that the exchange value of zeolites was discovered.

As far back as the middle of the last century, Way[2] published statements to the effect that the fertilizing properties of the soil were of a purely chemical nature, taking place in the presence of silicates with the power of exchange of bases in the soil. Leibig[3] op-

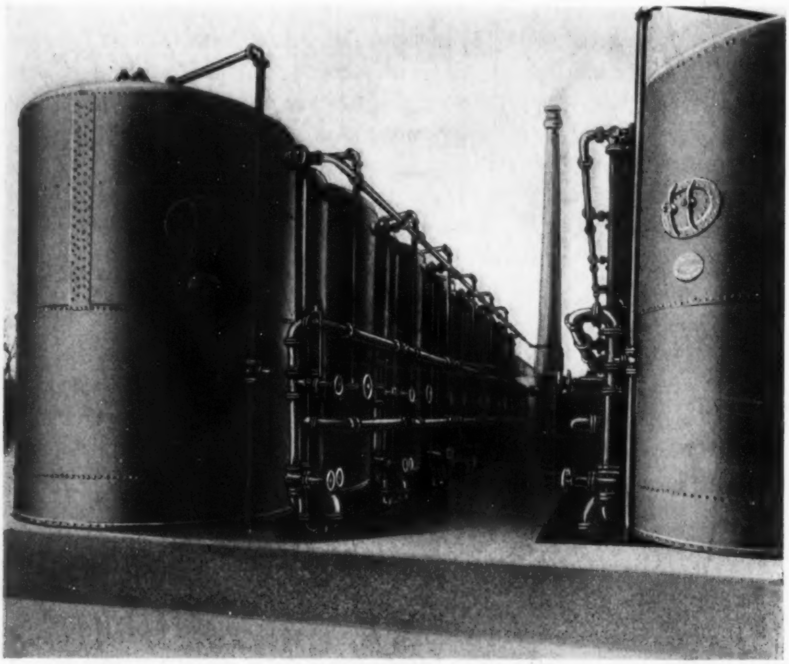
[1] Read and discussed at the Cincinnati convention May, 1915.

[2] *Journ. Agric. Soc. England*, 1850 and 1852.

[3] *Leibig's Annalen*, 1856.

posed this theory. Later on experiments by Lemberg,[4] Eichhorn,[5] Peters,[6] and others showed that natural zeolites exchange their bases for other bases contained in solution in contact with them.

The manufacture of artificial zeolites to prove theories was often attempted but the products obtained were either of a gelatinous, slimy character or of a hard, glassy structure with a small degree of exchange. With the exception of Rumpler,[7] who tried the use of silicates in the sugar industry but without success, nobody had previously attempted to use them for technical purposes.



MUNICIPAL WATER SOFTENING PLANT, HOOTEN, ENGLAND

It remained for Professor Gans[8] to thoroughly investigate the whole subject of the exchange value of soils; to collect and analyze

[4] *Zeitschrift der Deutschen Geologischen Gesellschaft*, 1870, 76, 77, 83 & 87.

[5] *Poggendorf's Annalen*, 1858, pages 105 and 126.

[6] *Landwirtschaftliche Versuchs stationen*, Bd. 2, page 113.

[7] *Die Deutsche Zuckerindustire, 1901, and Internationaler Congress fur angewandte Chemie*, 1903, Bd. III, pages 59 and 69.

[8] *Jahrbuch der Kgl. preussischen Geologischen Landesanstalt*, 1905 and 1906.

all the various zeolites and determine which had the highest exchange value, and finally to produce an artificial zeolite having much greater and more rapid exchange than those found in nature and also of pronounced physical toughness so that it might be successfully used for technical purposes. His attention was first drawn to the subject by noting that waters originally hard would become completely softened by passing through certain soils of volcanic origin, whereupon he investigated thoroughly the chemical nature of these soils and found them to be zeolites of more or less similar composition. He found also that some soils were very much more active than others and by studying these he developed an artificial compound having a formula which would give a very high softening effect. This led to the manufacture of an artificial zeolite through which water could be filtered as through a sand filter.

If a water containing lime and magnesia is passed through such a filter of zeolite of a composition of sodium-alumino-silicate, the sodium will be replaced by the lime and magnesia and the reaction will be the equivalent of what takes place in the old water softening process, except that the water is softened to the zero point, due to the absolute insolubility of the lime and magnesia zeolites formed in the filter.

By the use of this insoluble filtering material as a reagent, it is possible to employ a large excess of this reagent so that the removal of the undesirable bases from the liquid to be treated takes place automatically in the cold, and completely without having any excess of sodium salts in the effluent which is a decided advantage over earlier known methods of softening.

In order to form the ideal zeolite of minutely porous but strong structure, Dr. Gans melted together in a furnace the necessary mineral ingredients consisting of soda ash, feldspar, kaolin and pearl ash in the proper proportions, and the glass thus formed was heated with hot water, lixiviated, washed and sieved to the proper size. This material when used in a filter of the proper mechanical type and run at suitable rates had the power of removing all lime and magnesia from any type of water so that the effluent water would be absolutely zero in hardness. The size and rate of the filter depend upon the amount of water used and the hardness which it contains. The usual depth of filter is from 3 to 4 feet and the usual rate from 10 to 15 feet per hour when the hardness is from 10 to 20 degrees.

In the earlier lime soda process a reaction time of at least four hours is needed if a reduction of the hardness down to from 3 to 6 degrees is desired, and only a small excess of reagents in the effluent is allowed. By the zeolite process a reaction time of about two minutes for soft water; of three to six minutes for medium hard water and of seven to twelve minutes for a very hard water is needed to remove *all* of the hardness.

In this process the calcium and magnesium of the water exchange places with the sodium of the zeolite giving a sodium salt in solution in the treated water as shown by the following formulae:

Sodium zeolite	+ calcium salts	= calcium zeolite	+ sodium salts
$Na_2O \cdot Al_2O_3 \cdot 2SiO_2$	$+ CaCO_3$	$= CaO \cdot Al_2O_3 \cdot 2SiO_2$	$+ Na_2CO_3$
$Na_2O \cdot Al_2O_3 \cdot 2SiO_2$	$+ CaSO_4$	$= CaO \cdot Al_2O_3 \cdot 2SiO_2$	$+ Na_2SO_4$
$Na_2O \cdot Al_2O_3 \cdot 2SiO_2$	$+ Ca(NO_3)_2$	$= CaO \cdot Al_2O_3 \cdot 2SiO_2$	$+ 2NaNO_3$
$Na2O \cdot Al_2O_3 \cdot 2Sio_2$	$+ CaCl_2$	$= CaO \cdot Al_2O_3 \cdot 2SiO_2$	$+ 2NaCl$

Similar reactions also take place when magnesium salts form the second half of the equation instead of lime salts.

When the point is reached where the sodium of the zeolite has become sufficiently exhausted so that the reaction does not take place completely, then the filter is stopped and regenerated by running in an 8 per cent solution of common salt and allowing it to stand for about eight hours, when the following reaction takes place:

Calcium zeolite + common salt = sodium zeolite + calcium chloride

$$CaO \cdot Al_2O_3 \cdot 2SiO_2 + 2NaCl = Na_2O \cdot Al_2O_3 \cdot 2SiO_2 + CaCl_2$$

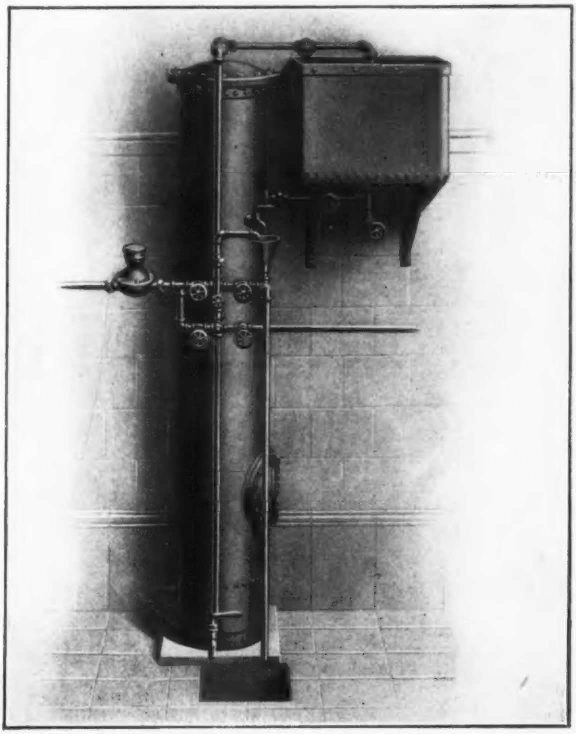
By this mass reaction of the common salt the zeolite is changed to its original composition. The salt solution containing the soluble lime and magnesium salts is then run off and the filter washed when it is again ready for use.

It is apparent that the filter will require little attention as there will be no shifting or changing of the proportion of the reagents due to fluctuations in hardness. The sodium of the salt goes back into place in the zeolite and the clear solution when run off contains all the lime and magnesia as soluble chlorides which may be run into any drain. The filter, after washing, is then ready for a second run.

This process may be kept up indefinitely with but slight losses of zeolite. The municipal laundries in Berlin had been running a filter for four years when inspected in 1912 and no replacements of

zeolite had been made during that time, while the capacity had in no way diminished. Waters very high in organic matter may require a certain percentage yearly replacement.

The whole series of alumino-silicates may be made from sodium alumino-silicate by simple replacements of the bases in various soluble salts and there are oxidizing, reducing and catalizing compounds which may be used for various purposes. The one most



HOUSEHOLD WATER SOFTENING PLANT

in use at the present time is manganese zeolite or permutit, which when treated with permanganate of potash makes a compound of high oxidizing value and is used for making filters for the removal of iron and manganese from water. Such filters have been extensively installed abroad, the largest ones are in Dresden, Germany, for the removal of manganese from the municipal supply, and in Hooten, England, for the elimination of iron from the water supply

of that town. At Hooten also is the municipal water softening plant.

The process also lends itself readily to small installations as it requires so little attention and may be employed in pressure filters which avoid an installation built high in the air or double pumping.

The cost of operation is the cost of common salt used which is from $2 to $8 a ton, depending upon the locality. If the water is five degrees in hardness then the cost is usually about 1 cent per thousand gallons.

In the household, water filtered through artificial zeolite is smooth and velvety for bathing, shaving and shampooing, and prevents rough skin and chapped hands. In the laundry it reduced the soap bills and prevents the muddiness which often comes from the precipitation of lime and magnesium soaps on the white goods. In the boiler it prevents scale and corrosion. The boiling time of vegetables is shortened and in some cases the flavor improved. Vegetables like peas are softer and less pulpy.

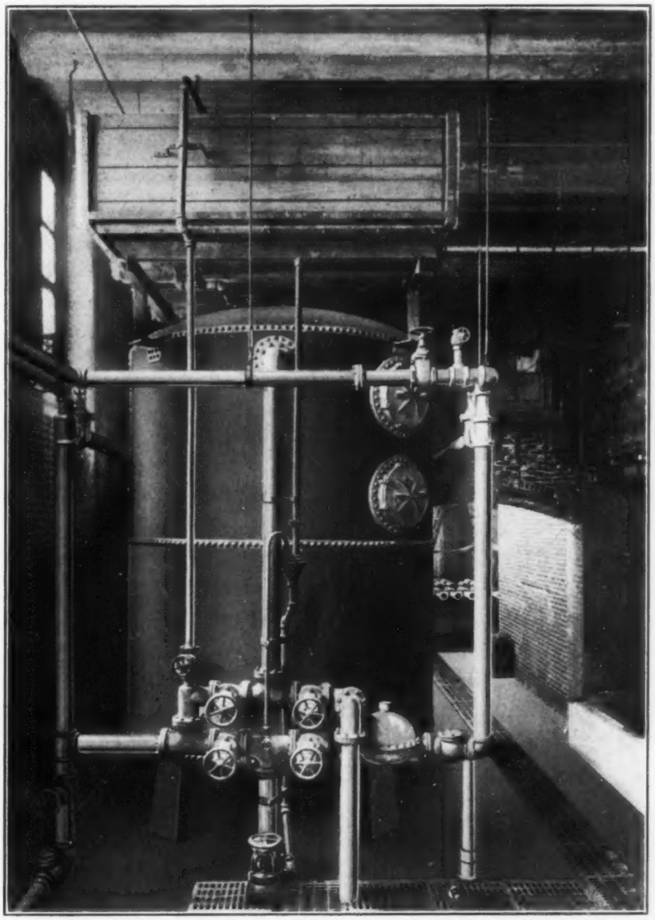
For drinking purposes it has been found that water softened in this manner gave much greater and more rapid digestibility of food than when softened by the lime soda process. This is undoubtedly due to the presence of bicarbonates which increase digestive action.

In the textile industries and public laundries the process is extensively used due to the saving of soap and the improvement in the quality and clearness of the goods. Even when moderately hard waters are used soap compounds which are impossible to remove may form small deposits on the surface of materials. In dyeing these deposits cause spots or blemishes or unevenness so that the general effect of the color is not as clear and bright as it should be and if the water fluctuates in hardness it is extremely difficult to match shades.

The Bradford woolcombers of England informed the writer on his visit there that the water filtered through zeolite rendered the wool softer and gave a larger percentage of the higher grades than when the water was softened by the lime soda process. The installation was smaller and required much less attention and always reduced the water to zero hardness which in this work was found to be of great importance.

The process has been in commercial use in Germany since 1908 and in the United States since 1911. It has been most extensively installed for the treatment of water for industrial purposes or for

boiler use, but some municipal plants have been constructed, notably at Hooten, England, where a water of 20 degrees of hardness is reduced to 10 degrees by treating one half of the supply consisting



FACTORY WATER SOFTENING PLANT

of one million and a quarter gallons, and mixing the zero water obtained with the other half to produce a water of 10 degrees of hardness.

DISCUSSION

MR. EDWARD WEGMANN: The speaker was always under the impression that soft water was best for health; but in reading descriptions of water works built in England, the engineers there state positively that in towns where they have hard water the people live longer than where they have soft water. That is contrary to what has been the speaker's conception. What do you think about that statement? A man prominent in engineering published that as a positive fact.

MR. DANIEL D. JACKSON: Someone has said that statistics are for the purpose of proving something that is not so; and it would seem in this case the statistics you refer to are chargeable with that imputation. The speaker believes, although of course there are all sorts of opinions, that it is much better to drink soft water. Certainly the lime salts in the waters which are drunk are not utilized physiologically as far as is known. Even if they were, there is probably more lime in a glass of milk than in several buckets of water; so that rickets and other things which have been attributed to soft water are practically eliminated from consideration. It is not probable that anything of that kind can be brought about by the use of soft water. One of the author's children was given only distilled water until he was six years old. He is now playing on football and baseball teams and so far he has broken no bones.

A MEMBER: Why is pearlash used in the preparation of zeolite; why is it added?

MR. DANIEL D. JACKSON: A very small amount of pearlash is added to make the mixture fuse at a little lower point, just as it happens in the case of materials in a chemical crucible. By the addition of potash feldspar and high heat you can get along without any pearlash at all.

A MEMBER: Did you say that you use 8 per cent of salt solution in regenerating zeolite, and that it removes the calcium and magnesium taken up by the gravel? Is there a waste of salt in that process, or is there a way of recovering the salt, or separating it from the chlorides of magnesium and calcium?

Mr. Daniel D. Jackson: If you have a reaction in chemistry, in order to get the reverse action you must have a very large excess of material, so an eight per cent salt solution is used for the purpose of getting what is called a mass reaction. In that case the sodium will go back into the zeolite again, and the calcium will come out as chlorides of lime and magnesia. As to being able to recover the salt, in some hotels where it is employed, the salt solution is used for a seabath, but it is so cheap that it would not be practical to recover it from the lime and magnesia to be used over again in the filter.

Mr. Edward Bartow: The Illinois State Water Survey has been interested for several years in the Permutit process. When the first publications appeared we purchased a small plant and tested it quite thoroughly in our laboratory. It was found that water could be obtained with zero hardness. Last summer, through the courtesy of the Permutit Company in Germany and the United States Softeners Company in England, several plants including some which Mr. Jackson has mentioned were visited. One or two of our observations may be of interest.

At a plant of the General Electric Company near Berlin, Germany, they used zeolite to soften the water to make tea. This company furnishes bottled tea to its employees, and the ordinary water did not give a sufficiently clear product. By use of the zeolite process to soften the water they got a perfectly clear, acceptable tea. In Bradford, England, the plant of the Woolcombers Limited has a combination lime, soda and zeolite plant, one of the largest installations, probably, in the manufacturing establishments. They use a water of 30 degrees hardness, 30 grains per imperial gallon, that is softened to the greatest extent possible with lime and soda, and then the hardness reduced to zero with zeolite. It was stated that the workmen using the water in the plant could immediately tell the difference between the water softened to zero by the zeolite process and water from the city supply, which had a hardness of only three or four grains per gallon. They reported a saving of two pounds of soap for each grain of hardness removed. In this country, a zeolite plant was put in in a little textile factory where they had used soap to soften the water; avoiding the use of any chemical for fear of injuring the goods. It was calculated that they would be able to save $2 per thousand gallons because of the amount of soap

that would be saved. After they tried the zeolite softened water they reported that the saving was $3 per thousand gallons as against the cost with the raw water. Of course a similar saving would have been made by softening the water in any way. This is just an illustration of what the possibilities are. Lime, soda and zeolite go well together. The combination is most often used in England.

Mr. Daniel D. Jackson: In one place in Germany they were making tea for a very large factory where there were 3000 employees, and work was stopped at noon that they might have their tea or their beer. The amount of tea that was originally used with hard water was just twice what they had to use after they had recourse to soft water; in other words, the essential oils in the tea were used up to a very large extent by the lime and magnesia in the water, but when the tea was made with soft water this did not take place, and they only had to use half the amount of tea. In this large concern that made quite a difference. Undoubtedly such a result as that might occur with oils of other character, possibly in tobacco and other materials which may be treated with water. Those are ideas which are yet to be developed.

A Member: Is soft water as palatable as hard water?

Mr. Daniel D. Jackson: If you have been used to drinking very hard water, and then change to soft water, you will not like it; and vice versa; but once you are accustomed to drinking soft water, it is very much better for you.

A Member: Why not use the natural deposits that you spoke about instead of the artificial?

Mr. Daniel D. Jackson: Because the percentage of exchange in the natural deposits which we know about is small as compared with the artificial material which is made up theoretically correct. In Germany some of these compounds have been used which were made and purified from zeolite stone; but you have a filter three or four times larger, and the results are not nearly as good, so that that method is hardly practicable.

A Member: Has zeolite softened water been used very extensively as boiler feed water, and what results were thereby obtained?

Mr. Daniel D. Jackson: There are hundreds of installations for boiler purposes in this country and all through the north of England, and particularly in Germany; and the result of using this water is that you do not get any scale whatever, you have clean iron with no scale and little or no corrosion. That is because the magnesia combined with chlorides and nitrates which produced the highest degree of corrosion are removed. When these are taken out of the water the corrosion is eliminated, so that you have a great saving in boiler operation.

A Member: What effect is there on the foaming quality of the water?

Mr. Daniel D. Jackson: If a water has something like fifty degrees of hardness, as it has in some places, the foaming will be a material detriment in that supply. If you have water which foams originally in the boiler, it will still foam when you soften it; in other words, softening the water does not reduce the foaming characteristics.

DIFFICULTIES IN THE DESIGNING AND OPERATION OF MEDIUM SIZED WATER WORKS PLANTS

By E. B. Black

In the early history of the development of the business of furnishing cities with an adequate supply of pure and wholesome water, the cost of such service was necessarily large, as is to be expected in the development of any commercial enterprise, so only those cities of sufficient size, or of such peculiar location that a fair return seemed possible on a considerable investment, could interest private capital in the building of water works systems.

The demand for the many advantages a modern water system brings a city comes as a result of education. Gradually the small cities and towns began to demand such improvements, and when private capital could not be interested on account of the limited revenue possible from a small community, special legislation allowed the building of systems by these small cities themselves. It seems now that a town of from 1000 to 5000 inhabitants can build a water works system, in some sections of the country at least, with as little trouble in financing the proposition as was formerly experienced in towns of 50,000 or 100,000.

Perhaps no other state has made possible the building of public utilities in the same way that Kansas has. With an allowable indebtedness of 15 per cent of the assessed valuation, and with the assessed valuation taken as the full value of property, it has been an easy matter to vote bonds for the purchase of existing systems or the building of new ones. Three years ago an emergency law was enacted by the state which allowed all cities and towns already owning their water works systems to issue bonds for necessary improvements until the total indebtedness of the municipality should reach 15 per cent. These bonds may be issued without vote of the people, the only requirement of the law being the approval of detailed plans, specifications and estimates of cost by the State Utilities Board prior to the issuance of the bonds.

All these things have worked together to stimulate the building

of new systems in the small cities and towns of Kansas, and the building of needed improvements in those towns already owning their systems, until now there is a total of about two hundred and fifteen water systems in the state, and about 90 per cent of the total number are in towns ranging from 500 to 4000 inhabitants. It may be of interest also to note that not more than a dozen of these systems are privately owned. While conditions in Kansas may have been more favorable than elsewhere in the past for the building of small water systems, such improvements have by no means been confined to that state, and the small cities and towns throughout the country, realizing the benefits coming from the establishment of such systems, have been actively shaping legislation so they also may have water systems.

The design and operation of systems in towns of small size present difficulties foreign to the design and operation of large plants. In designing, the services of an engineer are often dispensed with, and practically never is an engineer retained to advise relative to the operation of the system. This may be on account of the size of the proposition and the desire to put every dollar available into the improvement. Then again, the design may be handled by a concern manufacturing or selling equipment. Admitting the fact that such concerns may have the best engineering talent available, it is not reasonable to assume that other concerns will feel free to bid on their competitor's design; or that the proposal of the designer, if accepted without competition, will be either an efficient or economical one. Many small systems have been built by the contracting engineer. The design and the construction both frequently suffer in such cases. It is difficult for a man to design a system, bid on it with other bidders, and then construct under his own plans, specifications and supervision.

In some systems the poor ideas of the owner or city officials are followed; this is sometimes the case even when an engineer is retained. In going over a sewage disposal proposition recently, plans of the city's sewers were furnished. The engineer who had planned the sewers had evidently suffered from suggestions of various officials; for on one sheet of the profiles was this note,

> The number and location of Wye branches and manholes on this sewer were fixed by the city clerk and the plan does not therefore represent my ideas in the matter. Please refer to my letter of ——— date in this connection.

A short time ago a city retained engineers to design a storage reservoir to be used in connection with one already in use. The bottoms of both reservoirs were to be on the same elevation only a few feet from wall to wall, and the water was to be carried in both at the same levels. The superintendent asked that a syphon be used to get the water from one reservoir to the other. He had never built a syphon, here was his opportunity. This reason is probably responsible for more mistakes in construction than any other.

Some of you are familiar with a plant in which the discharge line from the pumps is carried up the outside and over the top of the standpipe supplying the town. This is a scheme evolved by one of the plant engineers, which enables the pumps to operate against a column of water only ten inches in diameter instead of one thirty feet in diameter, the size of the standpipe. You may have heard of the gravity flow line, the size of which was increased by sections from the upper to the lower end in order to overcome friction.

Some years ago the writer made an appraisal of a privately owned power plant for a town contemplating its purchase. The plant originally consisted of a generator, clutch connected to a line shaft driven by a water wheel. The time came when the water power was insufficient, so the line shaft was extended and two large gasoline engines belted to it from a single clutch pulley between them; so connected that either or both engines could help the waterwheel. But even then the power was insufficient at times, and at the time the plant was examined a traction engine was belted to the line shaft through a hole in the wall of the power house. The owner was even then looking for more power, and wondering why the plant did not operate satisfactorily. Some one had advised him that all well regulated plants kept records of ammeter and voltmeter readings. These had therefore been faithfully recorded each thirty minutes of the plant's operation; but the current generated was three phase and the readings had been taken from one ammeter and one voltmeter connected to one phase only.

These instances are not exceptions in the average small plant; indeed, many more serious mistakes are known to every plant operator. Water systems with no water supply, filtration plants that fail to filter, and many other such mistakes are matters of common knowledge. Practically all of these things can be traced back to a desire to save a few dollars of the original investment, at the

expense of comparatively greater cost of operation and maintenance. Even in the power plant, that part of the system where efficiency might be expected, and in plants where tests are made on the equipment at the time of its installation, provision is seldom made so the superintendent can run an overall efficiency test at any time, and the guaranteed efficiencies under which simple equipment is often purchased are frequently impossible of determination by the superintendent, after the plant has been turned over to him. Power plants are installed with separate guarantees on engines, boilers and generators; motor driven pumps with separate guarantees on motors and pumps. In the small plant and in many large ones, an "overall" efficiency guarantee is possible, and it is the only guarantee for which the superintendent has a great deal of use.

Efficient equipment in a plant counts for little unless you know that that equipment is maintaining its efficiency through efficient operation.

The man never lived who thoroughly enjoyed writing reports and weighing coal, or even changing record cards on recording instruments, but no plant can operate successfully and economically without an accurate and detailed record of its operation. In the small plant, recording instruments and labor saving devices, or even proper valves and meters are sometimes entirely lacking. How can an operator know what his plant is doing when he only knows how much coal he uses and how much money he takes in each month? Nearly all owners object to the size of the coal bill or to the amount paid out for chemicals for the filtration plant, but very few offer their superintendents expert assistance in cutting down the size of these bills. Business management does not entirely consist in keeping the operating cost within the receipts.

Two years ago the writer visited a privately owned water works plant, and inquired of the engineer in charge how much alum he was using, and how often he analyzed the water. His answer was that he used from three to six grains and that in the two years he had been connected with the plant no analyses had been made.

Perhaps one of the hardest problems for satisfactory solution from the standpoint of results, is the operation of filtration plants of small size, for practically every plant of 5,000,000 gallons or less per day has to be operated intermittently, thus presenting added difficulties over the operation of a large plant. Obviously more attention should be given to the design and operation of such plants.

It is certainly of prime importance that this phase of the question should be given study it has not been given in the past.

The large water works system is not the only one entitled to efficient operation, to dividends and to the enthusiastic support of its patrons. Perhaps the system using the extra line to the top of the standpipe had other much more serious defects in its construction, and with these corrected, it might have operated at a profit instead of a loss. In all probability the owner of the system, the superintendent of which increased the size of the lower sections of the flow line to avoid friction, wondered why his investment was greater than necessary to accomplish a given result. The owner of the filtration plant where no analyses had been made for atleast two years probably considered himself abused when patrons objected to the quality of water furnished.

There are good and sufficient reasons for about ninety-nine per cent of the defects of design and operation of the small water works system, and the successful owner or operator is the one who removes these defects by careful and intelligent design and operation. There is little real excuse today for poor design or unintelligent operation of the small sized water works systems. The various state boards of health have done, and are doing, a remarkably efficient work in the education of the owners and operators of plants from these standpoints, and associations such as the American Water Works Association, through publications and conventions, make it possible for every water works superintendent to get ideas adaptable to the proper solution of the problems of his own plant, and surely no engineer, owner, or superintendent is worthy of his position who fails in demanding the best design and best results of operation for the small as well as for the large system.

SOME ASPECTS OF CHLORINATION

By Joseph Race

Although the treatment of water by chlorine or hypochlorite has been very extensively practised for several years, it is a regrettable fact that comparatively few investigations have been made into this process with a view to elucidating the basic principles and the modifications required to meet various conditions.

When chlorination was first introduced for the sterilization of water and sewage, all that was required was the addition of the hypochlorite; after this the process was supposed to take care of itself. Now we realize that, to obtain the best results, the process requires careful supervision and close attention to certain points. It is the purpose of the author to draw attention to some of these details in this paper.

1. MECHANICAL ADMIXTURE

Due attention has not always been given to this phase of the chlorination problem because of the prevalent opinion that the all important point was contact period. The author has previously recorded[1] experiments made for the purpose of comparing the importance of these two factors. In 1914 a sedimentation basin was placed in operation at the mouth of the Ottawa intake pipe, and during July the hypochlorite solution was added at the entrance to this basin. The method of addition was by means of a perforated pipe which stretched across the entrance to the basin, and the bleach solution and water were there mixed as thoroughly as was possible without having recourse to mechanical methods. The basin was baffled and had a normal capacity equal to approximately two hours consumption (1.7 millions imperial gallons). The results obtained were as follows:

[1] *J. Soc. Chem. Ind.*, 1912, 31, 611–616, and 1915, 34, 931–934.

Available chlorine = 1.88 parts per million. Bacteria per cubic centimeter

	AGAR THREE DAYS AT 20° C.	AGAR ONE DAY AT 37° C.	B. COLI INDEX PER CC.
Raw water	410.0	104.0	0.280
Treated water	49.0	26.0	0.036
Percentage purification	88.2	75.0	87.500

During August the connection at the entrance to the basin was closed and the bleach liquor added directly to the suctions of the low lift pumps, which take water from the sedimentation basin and place it in the intake pipe under a small positive pressure until it reaches the high lift pumps. During both months the samples of treated water were taken from the well which receives the mixed discharges of the low lift pumps. The results for August were:

Available chlorine = 1.55 parts per million. Bacteria per cubic centimeter

	AGAR THREE DAYS AT 20° C.	AGAR ONE DAY AT 37° C.	B. COLI INDEX PER CC.
Raw water	448	100	0.600
Treated water	26	12	0.005
Percentage purification	91.9	88.0	99.200

These results, which are the averages of daily analyses, show that the efficient mechanical admixture produced much superior results with a smaller consumption of chlorine.

COLOR

The effect of color, as is well known, is to reduce the efficiency of chlorination and to necessitate the use of a much larger dose. This is well exemplified in the following table which gives the results of chlorination experiments on B. coli seeded into water. Water "B" was the raw Ottawa River water containing 40 parts per million of color, and Water "A," with a color of 3 parts per million, was produced from "B" by precipitating with sulphate of alumina and subsequently filtering. The B. coli count was made by platting out 10 cc. of water in neutral red bile salt agar and counting the typical red colonies. Counts were made after 24, 48 and 72 hours, but in this table only the 24 hour count is recorded. The counts at later

periods were made to determine whether the organisms were actually killed or the reproductive capacity merely delayed, as was observed on a former occasion.[2] In none of the experiments was any evidence obtained of any revival of the organisms.

TABLE 1

Colonies per 10 cc. of water. Temperature = 63° F.

CONTACT PERIOD	WATER "A." COLOR 3	WATER "B." COLOR 40		
	Available chlorine p. p. m.	Available chlorine p. p. m.		
	0.2	0.2	0.4	0.5
Nil	194	194	194	194
5 minutes	121	165	129	66
1 hour	7	95	20	1
5 hours	0	4	0	0
24 hours	0	1	1	0
48 hours	0	0	0	0

To obtain the same result with about one hours' contact at 63° F., it is necessary to use about two and one-half times as much chlorine with a water of color 40 as with one practically free from color. Somewhat similar results have been obtained at Montreal by Harrington.[3] For the greater part of the year St. Lawrence water free from color is obtained at the inlet at the Montreal intake pipe, and only requires approximately 0.3 parts per million of available chlorine for satisfactory treatment. During the spring floods the currents are altered and the Ottawa River water is obtained; this requires as much as 1.5 parts per million of chlorine, but a portion of this high dose is necessitated by the increase of turbidity. During the flood period the color is somewhat reduced but its effect in the chlorination efficiency is more than counterbalanced by the increase in turbidity.

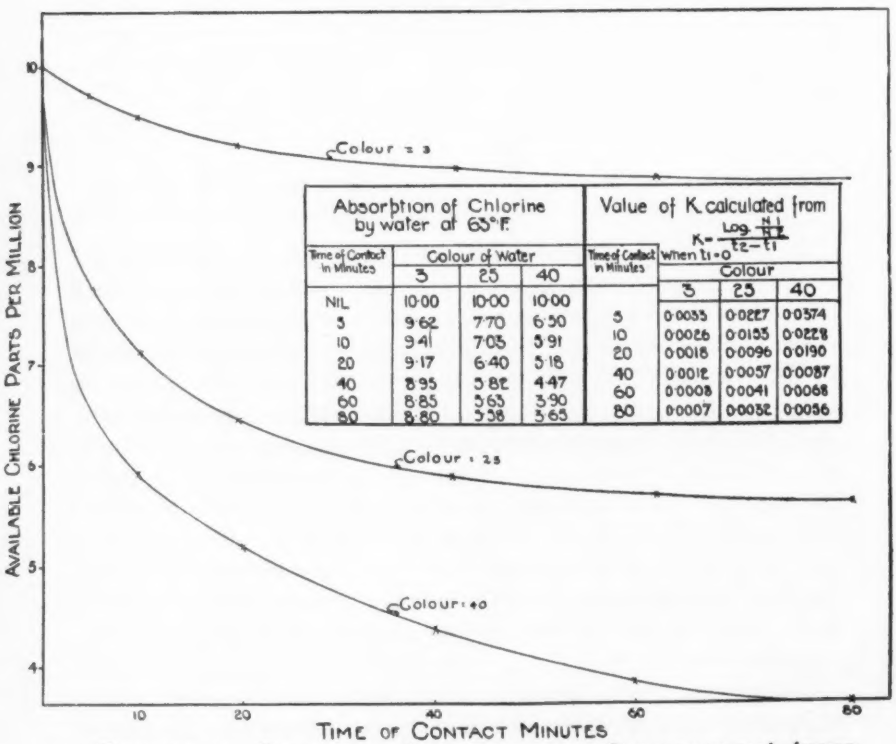
The effect of color upon the absorption of chlorine, in the form of hypochlorite, by water, is well shown in diagram 1. The absorption takes the form of a monomolecular reaction, the mathematical expression of this law being $\frac{dN}{dt} = KN$ where N is the concentration of the available chlorine in parts per million. Integrating between

[2] *J. Soc. Chem. Ind.*, 1912, 31, 611–616.

[3] Vide this Jour., Vol. I, No. 3, p. 438.

t_1 and t_2 we get the formula $K = \dfrac{\log \dfrac{N_1}{N_2}}{t_2 - t_1}$. If the compound absorbing the chlorine were simple in character, the value of K found would be constant in each experiment. Instead of that we find a constantly diminishing quantity, which is explained by the fact that the compound acted upon is not simple but a mixture of complex molecules having different affinities for oxygen.

DIAGRAM No. 1



Absorption of Chlorine by water at 65°F.				Value of K calculated from $K = \dfrac{\log \frac{N_1}{N_2}}{t_2 - t_1}$ when $t_1 = 0$			
Time of Contact in Minutes	Colour of Water			Time of Contact in Minutes	Colour		
	3	25	40		3	25	40
NIL	10·00	10·00	10·00				
5	9·62	7·70	6·30	5	0·0033	0·0227	0·0374
10	9·41	7·05	5·91	10	0·0026	0·0153	0·0228
20	9·17	6·40	5·18	20	0·0018	0·0096	0·0190
40	8·95	5·82	4·47	40	0·0012	0·0057	0·0087
60	8·85	5·63	3·90	60	0·0008	0·0041	0·0068
80	8·80	5·38	3·65	80	0·0007	0·0032	0·0056

EFFECT OF COLOUR ON ABSORPTION OF CHLORINE BY WATER

TEMPERATURE

The effect of temperature on a culture of B. coli in unsterilized water, color 40, is well illustrated in the two following tables.

TABLE 2

Effect of Temperature

Colonies per 10 cc. of water. Available chlorine 0.4 parts per million

CONTACT PERIOD	TEMPERATURE, DEGREES, FAHRENHEIT, 36	70	98
Nil	424	424	424
5 minutes	320	280	240
1.5 hours	148	76	12
4.5 hours	38	14	3
24 hours	2	0	0
48 hours	2	0	0

TABLE 3

Colonies per 10 cc. of water. Available chlorine 0.2 parts per million

CONTACT PERIOD	TEMPERATURE, DEGREES, FAHRENHEIT, 36	70	98
Nil	240	240	240
5 minutes	240	250	235
1 hour	245	235	195
4 hours	215	190	170
24 hours	143	130	115
48 hours	130	59	19
72 hours		28	
96 hours		16	
120 hours		6	

In the 70° F. experiment the sample, after 3, 4 and 5 days contact, was innoculated into lactose bile and lactose broth with the following results:

CONTACT PERIOD	LACTOSE		B. COLI PER 10 CC. MOST PROBABLE NUMBER		COLONIES PER 10 CC. ON REBIPEL-AGAR
	Bile	Broth	Lactose bile	Lactose broth	
72 hours	2/5	5/5	5	20	28
96 hours	0/5	4/5	1	16	16
120 hours	0/5	2/5	1	5	6

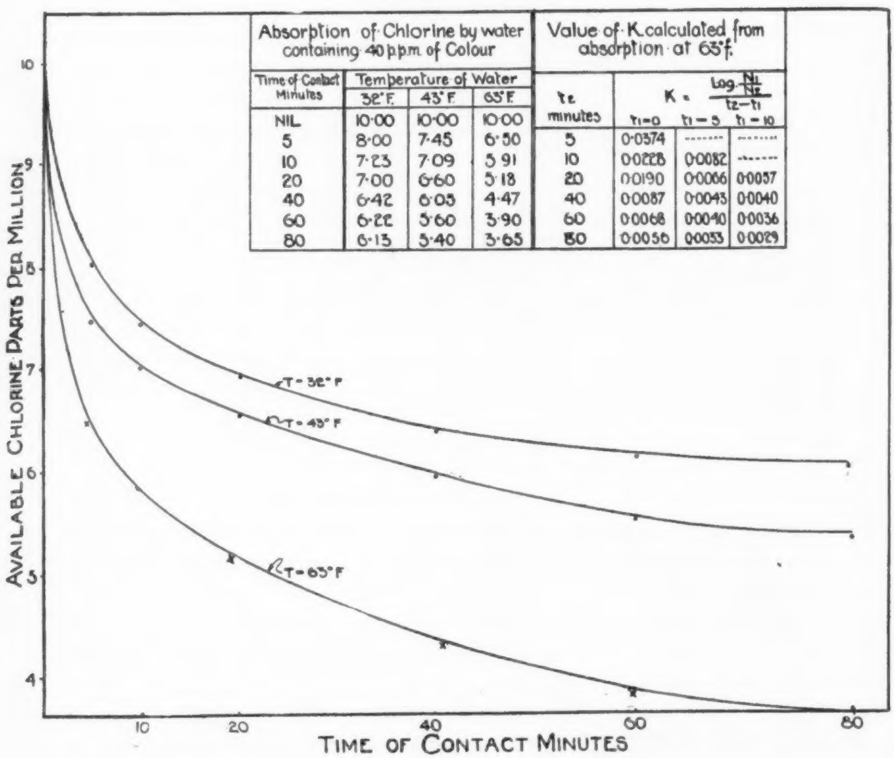
When these results are calculated to the most probable numbers by McCrady's method[4] some interesting comparisons are obtained. The lactose broth and rebipelagar plates are in close agreement but

[4] *Jour. Inf. Dis.*, 1915, 17, 183–212.

yield results very much higher than the lactose bile. If lactose bile only takes account of virile organisms it must be assumed that the majority of the B. coli remaining after 72 hours contact are attenuated. This dictum would appear to be somewhat arbitrary and empirical.

The effect of temperature upon the absorption of the available chlorine is shown in diagram 2.

DIAGRAM NO. 2



Absorption of Chlorine by water containing 40 p.p.m. of Colour

Time of Contact Minutes	Temperature of Water 32° F.	43° F.	63° F.
NIL	10·00	10·00	10·00
5	8·00	7·45	6·50
10	7·23	7·09	5·91
20	7·00	6·60	5·18
40	6·42	6·05	4·47
60	6·22	5·60	3·90
80	6·13	5·40	3·65

Value of K calculated from absorption at 63° f.

t_2 minutes	$K = \frac{\log \frac{N_1}{N_2}}{t_2 - t_1}$ $t_1 = 0$	$t_1 = 5$	$t_1 = 10$
5	0·0374	....	....
10	0·0228	0·0082	....
20	0·0190	0·0066	0·0057
40	0·0087	0·0043	0·0040
60	0·0068	0·0040	0·0036
80	0·0056	0·0033	0·0029

AFTERGROWTHS

In connection with chlorination, many well authenticated reports have been made that, after the preliminary germicidal action has subsided, a second phase occurs in which there is an accelerated growth of organisms. This is usually known as aftergrowth. When there

is only a short contact period between chlorination and consumption the reaction does not proceed beyond the first phase, but when the treated water is stored in service reservoirs the second phase may ensue, and is usually ascribed to a change in pabulum effected by the action of the chlorine or oxygen on the organic matter. Regarding the nature of this aftergrowth there has been considerable difference of opinion; some hold that it is the result of the multiplication of a resistant minority of practically all the species present in the untreated water; others that it is partially due to the bacteria being merely "slugged" or "doped," i.e., in a state of suspended animation, and afterwards resuming their anabolic functions; whilst others believe that, with the proper dose of chlorine, only spore forming organisms escape destruction and that the aftergrowth is the result of these cells again becoming vegetative. The aftergrowths obtained under the usual working conditions vary according to the dosage of chlorine employed, and none of the above hypotheses alone provides an adequate explanation. When the dosage is small a small number of active organisms, in addition to spore bearers, will escape destruction, and others, as was shown by the author in a previous paper,[5] will suffer a reduction of reproductive capacity. The flora of the aftergrowth in this case will only differ from the original flora by the elimination of species that are very susceptible to chlorine. As the dose is increased these two factors become relatively less important, until a stage is reached when only the most resistant cells, the spores, are left. The resultant aftergrowth must necessarily be entirely composed of spore forming organisms. Chlorination operators do not usually use a dose that would eliminate all but spore bearers, and it therefore becomes essential that we should know whether the aftergrowth has any sanitary significance. Concerning the secondary development of B. coli, the usual index of pollution, there is but very meager information. H. E. Jordan[6] reported that of 201 samples, 21 gave a positive B. coli reaction immediately after treatment, 39 after 24 hours standing and 42 after 48 hours. These increases were confined to the warm months, the cold months actually showing a decrease. The following figures taken from the author's routine tests for 1913 and 1914 show a similar tendency but an analysis of the results by months did not show that this was confined to the summer months.

[5] *Jour. Soc. Chem. Ind.*, 1912, 31, pp. 611–616.
[6] *Eng. Rec.*, 1915, May 17.

The sequence of the results from left to right in the following table is in the same order as the contact period, and each percentage represents the average of approximately 290 samples.

Percentage of samples showing B. Coli in 10 c.c.m.

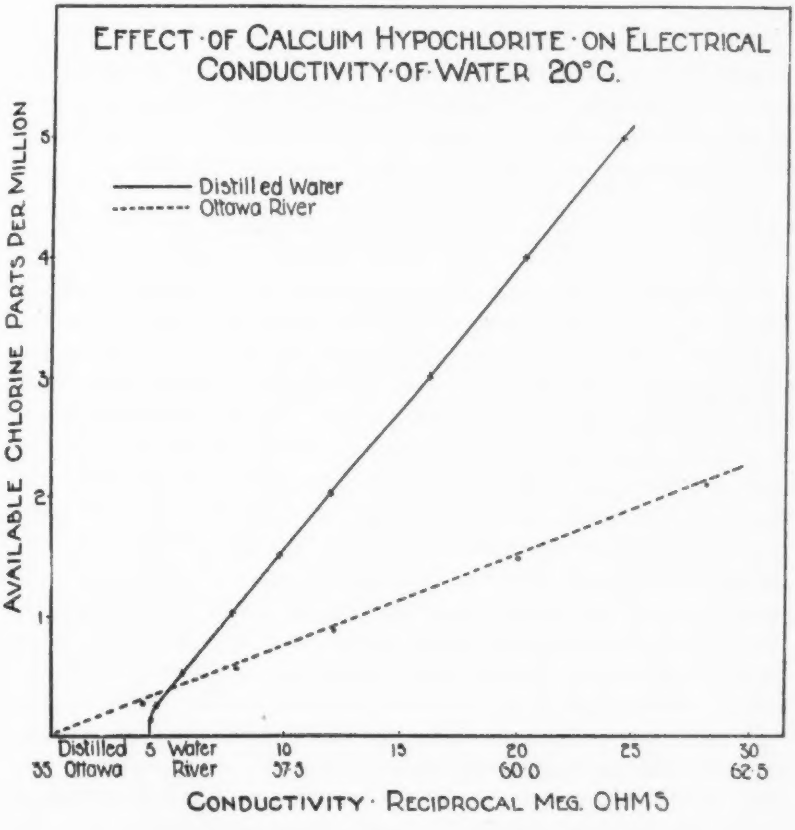
	1	2	3	4	5
1913	15.2	14.4	16.3	16.8	26.8
1914	7.0	5.7	6.0		11.6

At station 2 the germicidal action was evidently still proceeding but at station 5, representing an outlying section of the city, the increase is marked.

During 1915 and 1916 the author attempted to duplicate these results under laboratory conditions and entirely failed. Usually these experiments, which were made with the same materials as were in use at the city plant, but in glass containers, were only carried to 48 hours contact as this would be the extreme limit found in practice; one, however, was prolongued to 5 days. Many experiments of this nature were made with varying conditions, but as the results are all similar there is nothing to be gained by adding to those given in tables 1, 2 and 3. In every case there is a persistent diminution in the number of B. coli organisms found with increase of contact period. Determination of the bacterial count on nutrient agar showed in several cases that the aftergrowth had commenced, and in some instances there was evidence that the second cycle was partially complete, i.e., the number had reached a maximum and then commenced to decline. The time required for the completion of the two cycles, comprising the first reduction caused by the chlorine, the increase or aftergrowth and the final reduction due to lack of suitable food material, is dependent upon various factors of which the dosage and temperature are the most important. With a small dosage the germicidal period is short and the second phase quickly reached; with large doses the second phase is not reached within 48 hours. Low temperatures reduce the velocity of the germicidal action but extend the period over which it is effective. The higher the temperature the quicker is the action and the development of the aftergrowth. These statements refer only to the total bacteria as found by development on nutrient agar. The B. coli did not act in this way and persistently diminished in every case. If B. Typhosus acts

in a similar manner to B. coli, the laboratory experiments show that aftergrowths are of no sanitary significance, and can safely be ignored, but as the results obtained in actual practice are apparently contradictory the matter should be regarded as "sub judice" until more definite evidence is available. Perhaps the remarkable photochemical properties of chlorine are concerned in this matter.

DIAGRAM No 3



CORROSION

Numerous complaints regarding corrosion of piping systems in Ottawa led to the routine determination of free carbonic acid in the raw and treated waters. During a period of excessive turbidity and

pollution a very heavy dose of chlorine was used and an increase in the free carbonic acid resulted. During the past 18 months the average results show a decrease so that there could scarcely be an increased corrosive action due to carbonic acid.

If the treatment is considered according to the electrolytic theory, a slight increase in corrosion might be expected due to an increased electrical conductivity. The conductivities of various chlorinated mixtures were therefore determined with the results as shown in diagram 3.

With the usual dosages of chlorine it is inconceivable that the increased electrical conductivity has any practical significance at ordinary temperatures. At temperatures approaching the boiling point of water the percentage increase in conductivity would be somewhat greater, and may possibly assume practical importance.

SURVIVING TYPES OF B. COLI

Several experiments were made with a view to ascertaining whether the B. coli found after chlorination were more resistant to chlorine than the original culture. The colonies surviving after treatment with comparatively large doses were fished into lactose broth and this culture used for a second chlorination. The surviving organisms were again fished and the process repeated several times. The velocity of the chlorination reaction varied somewhat, but not always in the same direction, and the variations were not greater than were found in duplicate experiments with the original culture. No evidence was obtained that the surviving organisms were in any way more resistant to chlorine than the original culture. It should be remembered, however, that the surviving types were cultivated twice on media free from chlorine before being again subjected to chlorination. A number of the colonies surviving several chlorinations were cultivated in lactose broth, and the acidity determined quantitatively. All the cultures produced less acid than the original culture, and the average was materially less than the original cultivated under the same conditions. This points to a diminution in the biochemical activity.

A point of perhaps more scientific interest than practical utility is the relative proportion of the various types of B. coli found before and after treatment with chlorine. The author in 1914 commenced the analysis of the various types using the division of the American

Public Health Association by dulcite and saccharose as a basis. The averages of a large number of samples were as shown in table 4.

TABLE 4

	B. COLI COMMUNIS		B. COLI COMMUNIOR		B. LACTIS AEROGENES		B. ACIDI LACTICI	
	Raw	Chlorinated	Raw	Chlorinated	Raw	Chlorinated	Raw	Chlorinated
Ottawa, 1914	5	4	40	48	44	36	11	12
Ottawa, 1915	8	8	50	46	34	31	8	15
Baltimore, 1913*	11	14	33	25	35	31	21	30

* Thomas and Sandman, *J. Ind. and Eng. Chem.*, 1914, 6, p. 638.

Although there is a slight difference in the relative proportions of the types found at Ottawa and Baltimore, both sets of results show definitely that there is no difference in the resistance of the various types to chlorine.

DETERMINATION OF THE VALUE OF FIRE PROTECTION AFFORDED BY THE QUEENS COUNTY WATER COMPANY*

By Joseph Goodman

There are several private water companies operating within the city limits of Greater New York supplying an average of 38,000,000 gallons daily to a population of about 400,000. The city has been paying six of these companies $130,000 a year for hydrant rental in the shape of a fixed amount per annum per hydrant except in the case of the Flatbush Water Works Company which receives a lump sum per annum for fire service and most other public uses.

An investigation is now being made by the Department of Water Supply, Gas and Electricity of the entire plants of these companies with a view of determining their adequacy for furnishing a supply for domestic consumption and fire service. Appraisal of the companies' properties necessary and useful in the supply of water for domestic and public purposes, and inquiries into the proper allowances for current depreciation, operating expenses and taxes are being made for the purpose of establishing fair rates to private consumers; (in the case of three of the companies at present supplying 19,000,000 gallons daily the domestic rates are higher than the city's), also for determining the fair cost of fire service to be paid by the city, and for ultimate acquisition of the distribution systems by the city. Rates for water used for domestic and public purposes and for fire protection, based upon this appraisal, in the case of the Queens County Water Company, were recently established and put into force.

It is the purpose of this paper to outline in a general way the methods pursued in determining one of the problems involved in the investigation of this company, viz.: the determination of the value of fire protection afforded by it.

AREA AND POPULATION SERVED

The Queens County Water Company supplies the Rockaway peninsula, constituting the fifth ward, borough of Queens, New York

* Presented at meeting of New York Section.

City, including the former incorporated villages of Far Rockaway, Arverne, Rockaway Beach and the more recent developments of Belle Harbor, Neponsit and Edgemere, as well as a very considerable portion of the town of Hempstead, Nassau County. The Queens district now served by the company is about 7 miles long, with an average width of 1 mile. About 70 per cent of the company's business is done in Queens, while the bulk of the water supply, lands, wells and mechanical equipment, also a portion of the distribution system, lie within the county of Nassau.

The territory covered by the company's franchise, the districts supplied by it and the general relations of its property are shown on the accompanying map.

According to the last state census, the fifth ward in Queens has a permanent population of 21,000; this is more than doubled in the summer months. There is also a great influx of week end visitors who crowd the hotels and beaches merely for a day, or a few days at most. These conditions result in a comparatively very high peak load of water consumed during the summer months, especially on certain days in July and August. That part of Hempstead which the company now serves comprises roughly an area of about 30 square miles with a population of approximately 20,000. While there is an influx of summer population, it is relatively less than in Queens, and the peak load is less marked.

BRIEF DESCRIPTION OF THE COMPANY'S PLANT

The main source of supply is from a system of driven wells with an estimated capacity, as at present developed, of about 12,000,000 gallons daily, at the site of the Fenhurst pumping station near Valley Stream, Nassau County. Water is pumped from the wells into three slow sand filter beds, of a total area of $1\frac{1}{2}$ acres, to remove the iron; it is then repumped into the distribution system. The pumping equipment consists of nine pumps of a total rated capacity of 42,000,000 gallons daily; taking the double pumping into consideration and the necessity of maintaining a proper reserve, the actual safe capacity for continuous service is 16,000,000 gallons daily.

At Rockaway Beach there is a small auxiliary station, deriving its supply from three deep wells; it is operated during the hours of peak load on days of heavy draft at a rate of approximately 500,000 gallons daily.

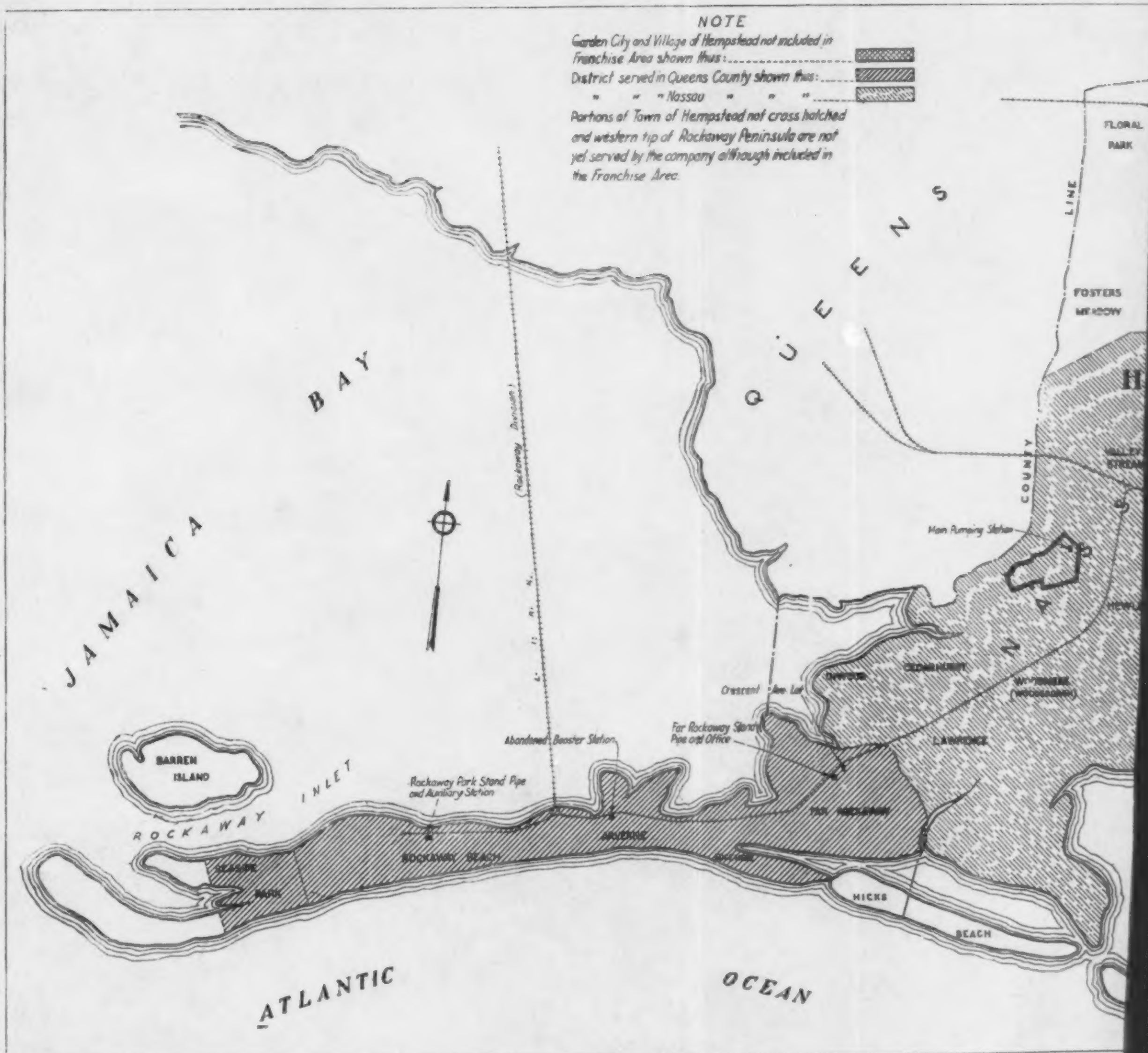
From the Fenhurst pumping station two 16-inch and one 24-inch trunk mains, each 4 miles in length, extend to Queens. The Queens distribution mains consist of 84 miles of mains ranging in size from 1½-inch to 24-inch; 7 per cent are 16-inch, 6 per cent 12-inch, 12 per cent 8-inch, 57 per cent 6-inch and 17 per cent 4-inch or smaller. A standpipe at Far Rockaway 20 x 140 feet and one at Rockaway Beach 18 by 130 feet are maintained on the system.

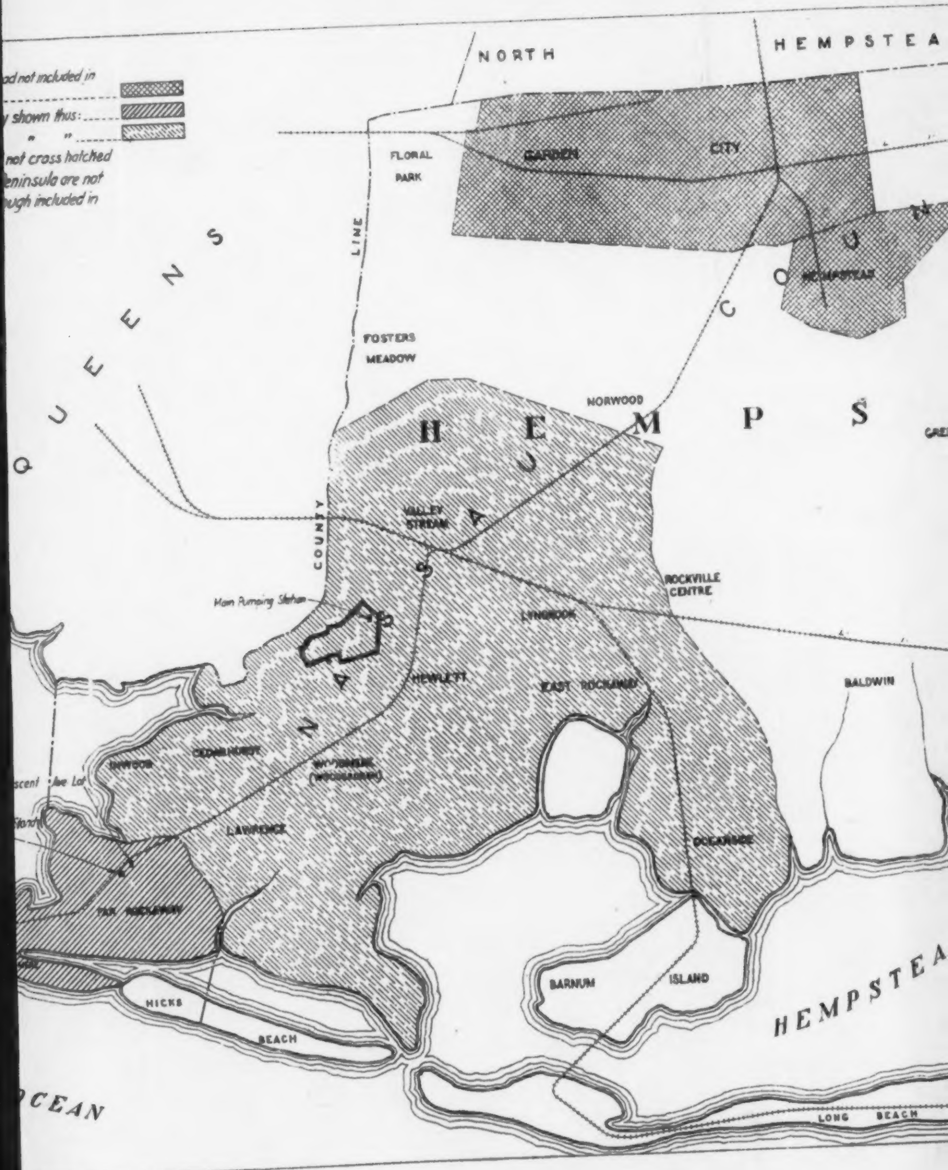
FIRE HYDRANT RENTAL

Under a contract which expired in 1902, the company was paid a fire hydrant rental of $20 per hydrant per annum, which sum also included the furnishing of water for certain public purposes. This price was based upon previous contracts with the villages and was fixed in 1898 by the Board of Public Improvements of the City of New York, for all private companies operating within the city limits, without adequate consideration of the cost of fire service or allowance for difference of conditions in different parts of the city. Since 1902 the company has continued to render service and has been paid therefor the rates previously prevailing.

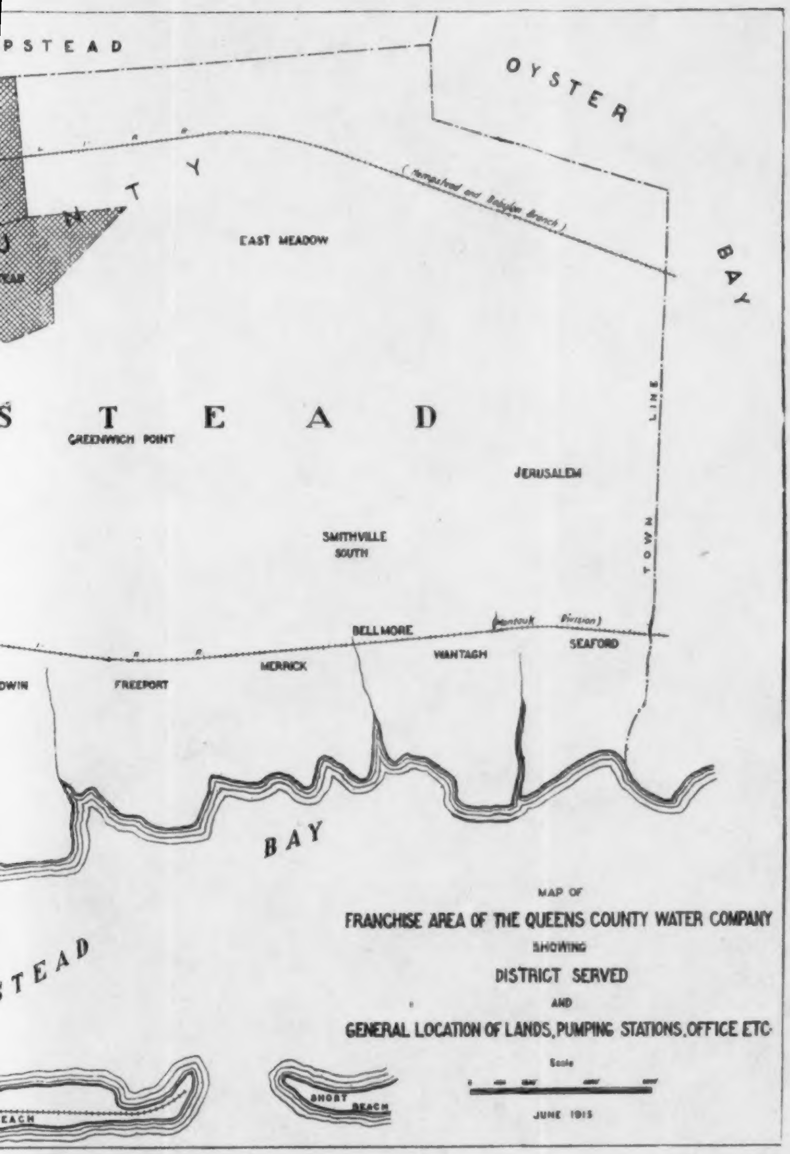
AUTHORITY OF THE COMMISSIONER OF WATER SUPPLY, GAS AND ELECTRICITY

The commissioner of Water Supply, Gas and Electricity of the city of New York is authorized under the charter, "to examine into the sources of water supply of any private company supplying the city of New York or any portion thereof, or its inhabitants with water, to see that the same is wholesome and the supply is adequate, and to establish such rules and regulations in respect thereof as are reasonable and necessary for the convenience of the public and the citizens." The commissioner may also "exercise superintendence, regulation and control in respect of the supply of water by such water companies, including rates, fares and charges to be made therefor, except that such rates, fares and charges shall not, without the consent of the grantee, be reduced by the said commissioner beyond what is just and reasonable; and in case of a controversy, the question of what is just and reasonable shall be finally determined as a judicial question on its merits by a court of competent jurisdiction."


NOTE
Garden City and Village of Hempstead not included in Franchise Area shown thus:
District served in Queens County shown thus:
" " " Nassau " " "
Portions of Town of Hempstead not cross hatched and western tip of Rockaway Peninsula are not yet served by the company although included in the Franchise Area.
FLORAL PARK
LINE
FOSTERS MEADOW
COUNTY
Q U E E N S
J A M A I C A
B A Y
(Rockaway Division)
Main Pumping Station
Crescent Ave. Lot
Far Rockaway Stand Pipe and Office
Abandoned Booster Station
Rockaway Park Stand Pipe and Auxiliary Station
BARREN ISLAND
R O C K A W A Y
I N L E T
ROCKAWAY BEACH
ARVERNE
FAR ROCKAWAY
LAWRENCE
HICKS
BEACH
ATLANTIC
OCEAN



ad not included in
shown thus:
not cross hatched
Peninsula are not
ugh included in
NORTH
HEMPSTEA
FLORAL PARK
GARDEN
CITY
HEMPSTEAD
QUEENS
LINE
COUNTY
FOSTERS MEADOW
NORWOOD
H E M P S
N A S S A U
C O U N
VALLEY STREAM
ROCKVILLE CENTRE
LYNBROOK
Main Pumping Station
HEWLETT
EAST ROCKAWAY
BALDWIN
INWOOD
CEDARHURST
WOODMERE (WOODSBURGH)
LAWRENCE
OCEANSIDE
FAR ROCKAWAY
BARNUM
ISLAND
HICKS
BEACH
HEMPSTEAD
LONG BEACH
OCEAN



MAP OF
FRANCHISE AREA OF THE QUEENS COUNTY WATER COMPANY
SHOWING
DISTRICT SERVED
AND
GENERAL LOCATION OF LANDS, PUMPING STATIONS, OFFICE ETC.
Scale
JUNE 1915

APPORTIONMENT BETWEEN QUEENS AND NASSAU DISTRICTS

Since the jurisdiction of the commissioner as to rates extends only to the portion of the company's territory lying within the city limits, it was necessary to determine the relation between the company's earnings in Queens and the portion of its investment properly chargeable to it. The latter was determined as follows:

All domestic services are metered; the actual metered consumption during the summer months of June, July and August was 2,766,000 gallons a day in Queens, and 802,000 gallons a day in Nassau; the sum of these was 77.3 of the pumpage figured. The pumpage was apportioned in the foregoing metered ratio of 77.5 per cent to 22.5 per cent. The average maximum hourly rates during the summer months were found from the pumping records to be 75 per cent greater than the average daily rates for the same period. The average peak load of pumpage during the hours of maximum use was thus established at 6,200,000 gallons a day (2,766,000 ÷ 77.3 per cent × 1.75) for Queens and 1,800,000 gallons a day (802,000 ÷ 77.3 per cent × 1.75). To these average peak loads for the two areas was added a maximum fire rate of 7,000,000 gallons a day for Queens and 3,000,000 gallons a day for Nassau, resulting in a ratio of 73.4 per cent of the total capacity chargeable to Queens and 26.6 per cent to Nassau. This ratio was applied to the investment in the pumping plant, buildings and general equipment.

To distribute the investment in the trunk mains in Nassau serving both Queens and Nassau, a further adjustment was made on account of the fact that the Queens supply was all delivered at the city line, while the Nassau supply was taken off at different points, and partly through a separate main; a ratio of 76.8 per cent to 23.2 per cent was established for these trunk mains.

For the well system, suction lines, filters and lands, a ratio of 72.4 per cent and 27.6 per cent was established, based upon the total pumpage during the summer months plus fire reserve, it having been assumed that the reserve in the filter beds and standpipes would take care of the hourly peak.

The allocation of investment as between Queens and Nassau services may be summarized as follows:

	QUEENS	NASSAU
	per cent	*per cent*
Land	72.4	27.6
Water supply sources and works	72.4	27.6
Buildings and mechanical equipment	73.4	26.6
Tools and supplies	73.4	26.6
Trunk mains in Nassau	76.8	23.2

GENERAL PROCEDURE ADOPTED TO DETERMINE COMPENSATION FOR FIRE PROTECTION

To determine the compensation for the fire protection furnished by the company in Queens, which is paid by the city at large, the following procedure, which is also being used in cases of the other private companies operating within the city limits, was adopted: The investment in various portions of the existing plant as actually constructed for both domestic services and fire protection was ascertained; an estimate was then made of the investment in the various portions of the plant necessary to make them fully adequate for domestic service without reference to fire protection. The difference between the two figures was regarded as the portion of the investment chargeable to fire service. This proportion was applied to the total investment chargeable to the Queens service, and the cost of fire protection properly chargeable to the city for the Queens area was estimated upon the basis of a fair return upon the extra capital invested in this service, together with a proper allowance for depreciation, taxes, maintenance and operation.

Since the major portion of the investment chargeable to fire service would remain the same irrespective of the number of fire hydrants in use, the cost of fire service was divided into two parts: First, the cost attributable to the general fixed investment, which would be measured as a lump sum per annum, and second, the cost attributable to the particular investment in, and maintenance of, fire hydrants, which would be measured in the form of a fixed sum per hydrant per annum.

The plant was established primarily for the purpose of selling water to private consumers at a profit and the adaptation to the demands of the general public for fire protection has been rather incidental to the main purpose of the enterprise, although payment for fire hydrant rental was undoubtedly anticipated. The basis adopted

for estimating the proportion of the cost of the service chargeable to fire protection, in this instance at least, was therefore deemed more equitable than the plan followed by the Wisconsin Commission of assigning the investment in the existing plant to fire service and to domestic use in proportion to the relative costs of two assumed independent plants, one for domestic service without fire protection and the other adequate for fire protection without regard to domestic service.

CAPACITY OF THE SYSTEM FOR FIRE PROTECTION

Preliminary to the work of valuation, and incidental to it, an investigation was made of the entire plant as to its adequacy for providing domestic service and fire protection. The capacity of the trunk mains in Nassau was computed from the delivery head at the pumps and elevation of the Far Rockaway standpipe. The capacities and gradients at different points in the Queens distribution system were computed and the available fire service in excess of the maximum domestic consumption determined.

On a Monday at the end of July when the domestic draft was close to a maximum, tests were made of the flow from groups of hydrants at representative locations in the distribution system. These locations were selected according to the character and occupancy of the buildings where good fire protection was deemed necessary. The hydrants in each group were opened simultaneously and allowed to flow freely for a period of about two minutes, the discharge from each hydrant being found by a Pitot tube gauge. At the same time static pressures were taken in the mains above and below the hydrant group, starting about ten minutes before and continuing for the same period after the hydrants were shut down. The pumping records, pressure gauge charts and elevations of water in standpipe during the tests were obtained and supplementary tests were made on dead end mains, especially 4-inch.

The results of the tests were conclusive indications of the necessity of additional mains as determined by the computations.

It was considered by members of the Fire Department that for the development in Neponsit, Belle Harbor and Rockaway Park, consisting mostly of detached cottages, six fire streams, of 250 gallons per minute each, would furnish ample protection; for Seaside, Holland and Arverne, bounded by Fifth Avenue on the west and

Park Avenue on the east, as well as for sections of Far Rockaway and Edgemere, consisting of closely built-up areas of two and three story buildings, twelve streams would be sufficient; for Arverne east of Park Avenue, eight streams, and for Lawrence, Cedarhurst, Woodmere and Hewlett, in Nassau, from six to eight streams.

The fire engine companies in the fifth ward with the arrangement for emergency help from the mainland via the Long Island Railroad, could furnish 18 fire streams of 250 gallons per minute each. It was conceded that a conflagration in the fifth ward requiring a rate of delivery of between 6,000,000 and 7,000,000 gallons daily was possible.

These figures agree closely with the general recommendations of the National Board of Fire Underwriters for a minimum of 1500 gallons per minute in outlying residential districts, 3000 to 5000 gallons per minute in densely built residential sections of two and three story buildings, and from 5000 to 10,000 gallons per minute in densely built residential sections containing large area buildings and buildings four stories and higher.

ALLOCATION OF QUEENS INVESTMENT BETWEEN DOMESTIC SERVICE AND FIRE PROTECTION

The proportion of the value of the mains and appurtenances in the fifth ward chargeable to fire protection was obtained by laying out a distribution system that would give adequate service for domestic consumption only, and obtaining the difference in cost between such a system and the existing one. This gave 26.2 per cent as the proportion chargeable to fire protection.

With the strengthening of the distribution system recommended, the proportion of the mains and appurtenances in the fifth ward chargeable to fire protection, figured in this manner, would be increased from 26.2 per cent to 36 per cent. The distribution of the investment in the trunk mains in Nassau County was arrived at by similar methods.

In regard to water bearing lands, wells and suction lines, it was estimated from the records of suction lift and pumpage that the maximum capacity of wells as at present developed, was 12,000,000 gallons daily. The average peak load for domestic service during the summer months is approximately 8,000,000 gallons daily and it was assumed that any peak load in excess of this, for a brief period,

could be readily taken care of without a well capacity in excess of 8,000,000 gallons and that the storage of 1,500,000 gallons in the filters would furnish the balance of water required for fire protection, the raw water being pumped directly into the system in case of emergency. It was therefore estimated that two-thirds of the developed well capacity and two-thirds of the investment in wells, suction lines and water bearing lands were attributable to domestic service, leaving one-third as the extra investment made necessary on account of fire service.

In determining the distribution of cost between domestic and fire service of the buildings, mechanical equipment, coal storage and railroad siding, it was assumed that

1. For all buildings not directly contributory to the pumping of water, 100 per cent shall be charged to domestic service.

2. For all buildings contributory to the pumping of water, 75 per cent of the cost shall be charged to domestic service and 25 per cent to fire; this was based upon the estimated cost of housing and equipment with a capacity of 8,000,000 gallons a day.

3. For all apparatus, equipment and plant contributory to the pumping of water, the distribution of cost shall be 50 per cent against domestic service and an equal amount against fire service. This proportion was based upon the ratio of the safe continuous capacity of the pumping plant to capacity for average domestic peak load.

The investment attributable to the Queens service is given in the table on the following page.

OPERATING EXPENSES

The entire plant being operated as a whole, the exact distribution of expenses between the Queens and Nassau services, widely different in character, was very difficult. It was decided to distribute administration expenses, including salaries, office supplies and office expenses, meter reading, inspection and collection on the basis of gross revenues in the two districts. The expense of operating the pumping station and filters at Fenhurst, the maintenance of boilers, machinery and wells, of brooks and streams, was distributed on the basis of the total amount of water consumed in the two areas. The expense of maintaining the mains was distributed on the basis of the investment in mains attributed to the two services. The expense of maintaining the meters and hydrants was distributed ac-

cording to their respective numbers. The expenses of the Rockaway Park Auxiliary Station were all assigned to Queens. Fire insurance and maintenance of buildings were distributed according to investment in buildings, maintenance of standpipe at Rockaway Park was assigned to Queens and that at Far Rockaway was divided equally between Queens and Nassau. The expense of permits and tapping was distributed according to the number of new taps placed during the preceding four years, respectively.

The distribution of the operating expenses attributable to fire service was gone into with similar detail.

	DOMESTIC SERVICE	FIRE PROTECTION
Property attributed exclusively to domestic service		
Meters, corporation cocks, valve boxes and manholes in Queens other than hydrant valve boxes, and on trunk mains in Nassau, filters, electrical equipment, coal storage, railroad siding, buildings at Far Rockaway, tools, supplies and miscellaneous equipment, going value	100 per cent	
Property attributed in part to domestic service and in part to fire protection		
Trunk mains in Nassau	78.3	21.7
Valves on trunk mains in Nassau	78.6	21.4
Land used for wells and pumping stations	66.7	33.3
Wells and suction lines	66.7	33.3
Building and chimneys at pumping stations	75.0	25.0
Boilers, pumps and auxiliaries	50.0	50.0
Mains in Queens	78.0	22.0
Pavements over mains in Queens	70.0	30.0
Valves other than hydrant valves in Queens	81.3	18.7
Standpipes	50.0	50.0
Property attributed exclusively to fire protection		
Hydrants and connections in Queens		100.0
Hydrants valves in Queens		100.0
Hydrant valves boxes in Queens		100.0
Total	76.8 per cent	23.2 per cent

The company showed that it kept certain employees and certain extra telephone equipment solely as a protection in case of fire emer-

gency. Accordingly, 6 per cent of salaries, 40 per cent of office expenses, mainly telephone, and 10 per cent of pumping station wages were charged to fire protection. It was estimated that the expense of the Rockaway Park auxiliary station should be divided half and half between fire protection and domestic service. Of the cost of maintaining mains, 10 per cent was attributed to fire protection and the cost of cleaning pipes was distributed between domestic service and fire protection on the same basis that the investment in mains had been distributed, namely, 74 per cent for domestic service and 26 per cent for fire protection. Of the cost of maintaining the boilers, pumping machinery and buildings, 25 per cent was attributed to fire protection. The cost of maintaining standpipes was divided half and half. The cost of maintaining wells was divided in proportion to the distribution of the investment in wells, namely, 67 per cent to domestic service and 33 per cent to fire protection. Taxes were distributed in proportion to the investment, that is to say 74 per cent to domestic service and 26 per cent to fire protection. The cost of fire insurance was distributed on the same basis as the capital investment in buildings, boilers and pumps, namely, 62 per cent for domestic service and 38 per cent for fire protection. Stable and garage expenses were analyzed in detail with the result that 20 per cent was attributed to fire protection and 80 per cent to domestic service. A detailed examination of the bills of counsel led to the conclusion that about 20 per cent of the legal expenses should be attributed to fire protection.

The distribution of operating expenses attributable to the Queens area between domestic service and fire protection is given in the table on the following page.

FINAL RESULT

The net result of the method outlined, applied to conditions existing at the time of the appraisal, was a finding that 23 per cent of the total Queens investment and 15 per cent of the operating expenses and taxes were attributable to fire protection. With the allowance for depreciation and interest on investment, the cost of fire protection was found to be approximately 21 per cent of the total. The rates for "fire hydrant rental and fire protection" were fixed as follows: "For each fire hydrant set and maintained at the request of the city of New York, as a proper return on the special investment

Class of Expense	Percentage attributable to domestic service	Percentage attributable to fire protection
Salaries	94.0	6.0
Stationery and office supplies	100.0	
Office expenses (including telephone)	60.0	40.0
Operation of pumping stations:		
Wages	90.0	10.0
Coal	100.0	
Oil, packing, waste, light	100.0	
Minor equipment	100.0	
Rockaway Park Station	50.0	50.0
Reading meters	100.0	
Bottling	100.0	
Stable and garage expenses	80.0	20.0
Operation of filter	100.0	
Brooks and streams	100.0	
Maintenance of mains	90.0	10.0
Maintenance of boilers	75.0	25.0
Maintenance of machinery (including pumps)	75.0	25.0
Maintenance of buildings	75.0	25.0
Maintenance of meters	100.0	
Maintenance of standpipes	50.0	50.0
Maintenance of wells	67.0	33.0
Maintenance of hydrants		100.0
Maintenance of tools	100.0	
Cleaning pipes	74.0	26.0
Permits and tapping	100.0	
Inspection and collection	100.0	
Fire insurance	62.0	38.0
Life insurance	100.0	
Miscellaneous expenses	100.0	
Legal expenses	80.0	20.0
Taxes	74.0	26.0
Total	85.0	15.0

devoted exclusively to public purposes, and to cover maintenance thereof and depreciation and taxes thereon, $8.70 per annum. As a proper return on that portion of the general investment made necessary by the need for fire protection, and to cover maintenance thereof and depreciation and taxes thereon, and for water reasonably necessary for sprinkling streets and for flushing streets and sewers, where such water is taken from fire hydrants, $30,000 per annum." Water for public purposes, except such as obtained from hydrants, is to be paid for at the established meter rates.

Under the old system the company would have been paid by the city $12,460 for fire hydrant rental for the 632 hydrants on the company's mains against the new rate of $35,498; this increase was offset by a corresponding reduction in domestic rates. The new rate was equivalent to $56 per hydrant, which unit cost, however, will be reduced as the number of hydrants is increased.

The gross earnings of the company on the Queens business during the year ending May 31, 1914, was, in round figures, $173,000.

Assuming a fair return of 7 per cent on the company's investment, the gross earnings to cover operating expenses and taxes, depreciation and return on investment was found to be $167,000. The difference of $6000 plus the increased payment by the city for fire protection of $23,000 gave a total reduction of $29,000 from the revenue obtained from domestic consumers and the rates were correspondingly reduced.

The investigations were made during the past year under instructions from Mr. Delos F. Wilcox, deputy commissioner of Water Supply, Gas and Electricity, those interested are referred for further details to his full report "In Relation to the Queens County Water Company" dated June 1, 1915, made to Hon. William Williams, commissioner of the department.

DISCUSSION

Mr. Louis L. Tribus: Mr. Goodman has presented a number of items of considerable interest in connection with the study of fire protection as furnished by the Queens County Water Company, in portions of Queens and Nassau Counties, New York.

The subject of remuneration for fire protection has rarely been given the best kind of study, though it is a very important feature in the service rendered by a water plant. It is very difficult, however, and probably unwise to attempt to deduce a general rule that would purport to have general applicability, from any particular case, for most communities have their own individual peculiarities.

The payment for fire protection is the communities expression of interest and participation in the work of a water plant. It is a matter of vital importance where a private company is rendering the service and is a matter of large importance where the community is itself doing so, for the receipts for fire protection have a bearing upon the rates payable for domestic and manufacturing use also.

As to the Queens County Water Company, the speaker has been familiar with its conditions from practically the inception of the company; he was associated with its first chief engineer and superintendent.

In the early days of the company's operations, its chief supply of water was derived from a series of driven wells located along the line of the Long Island Railroad in Far Rockaway, but over draught brought salt water infiltration and some evidence of sewage contamination, consequently the ruin and abandonment of the plant. As then situated the question of fire protection from the physical viewpoint presented no unusual difficulties or peculiar conditions.

When, however, the new supply was developed many miles to the northeast, and increased quantities had to be furnished miles to the southwest, the furnishing of adequate fire protection became a very important feature in the design of the plant and the company's operations in general. The territory covered, included a large area sparsely settled comparatively near the new pumping plant; to the westward, the village of Far Rockaway fairly well built up and covering considerable area; then a long neck of land but sparsely occupied, and still further to the southwest a long and narrow tract densely occupied in large part by amusement resorts of very flimsy construction.

Except in small districts the whole territory has been inhabited for but a few months during the summer season. Fire protection, however, has to be maintained throughout the year though the actual risk during the closed season is not specially great.

In an ordinary community the insurance companies would be right to differ from that opinion and the speaker would not express it, for there would be sufficient occupancy of many of the buildings during the winter season to cause a certain amount of risk from overheated furnaces, stoves, etc., but the closing is so complete in much of the territory served by the Queens County Water Company that danger points are few in number.

To furnish adequate fire pressure with the pumping station 6 or 7 miles away from the district of greatest risk with a considerable area to be first supplied with water makes a problem quite difficult of solution; that is, without entailing undue pressure upon the pumping machinery and an unnecessary pressure throughout the larger district, or as an alternative, a large main for the exclusive use of the western territory without any earning value for much of its length.

The company has tried to solve these various problems by means of adequate mains, two standpipes, a supplemental station and rather heavy pumping pressure at times. These steps have resulted in giving serviceable and adequate fire protection throughout the whole territory for the whole period of years in which the system has been maintained.

There have been two general theories of public payment for fire protection, both of course predicated upon the supposed value of the service rendered, with fairness to the public and justice to the company.

The more general method that has prevailed has been an annual payment per hydrant in place, at rates ranging from \$100 down to as low as \$5. These rates were primarily fixed by clever promoters negotiating with officials who desired to secure a water system for the community and who knew little of the value of the service, other than by the representations made, and usually confirmed, that fire insurance rates would be materially lowered after the water system was put in operation. The lowering of rates from $\frac{1}{4}$ to $\frac{1}{2}$ represented a gross saving for the average community, in any case, in excess of the prospective hydrant rental, so that it looked like a good bargain from the community's standpoint. In the promoter's eyes the hydrant rental would virtually cover the interest upon the prospective bonded debt, so that both parties were satisfied. Such contracts were usually made to run as long as the franchise periods, from 20 to 50 years and sometimes with the privilege of purchase by arbitration, or renewal of franchise and continuance of rental, etc.

The history of some of these transactions would be interesting but has little to do with the subject before the association, other than to indicate the customary way of arriving at a price. As franchises expired and contracts became renewable, more attention was paid to the real value of the service. By such time either the company was on a basis of fair money making, or had perchance passed through bankrupcty and the new owners becoming possessed of a valuable plant for a fraction of its real cost, gave less thought to the fire protection return, consequently if the same system of charging continued, it was at some arbitrarily agreed upon lower rate. Such rate had little bearing upon the value of the service given, representing simply a bargain or compromise.

It has been felt by many, however, who have given this subject consideration that better methods could be worked out to represent

a fair return. When a water plant is comparatively small, the size of the mains in order to furnish adequate fire protection must be very much larger than would be necessary for ordinary domestic consumption.

In a place needing a comparatively small water system, the buildings are as a rule not abnormally high, consequently the pressure of domestic service need not be as great as required for fire protection.

Again, the use for domestic purposes has very much less variation throughout the busy hours of the day than that required for fire fighting. With these factors calculated, it becomes a fairly easy matter to estimate the larger sized plant required to give the greater flow in a short length of time, and the greater pressure required for fire service than that needed to meet the named conditions for domestic uses solely. An estimate of cost of the two plants then gives a fair basis upon which to compute the annual return to represent a fire protection charge. Of course to this must be added the expense of placing and maintaining fire hydrants, the extra cost of running the larger pumps and in general what might be called the "ready to serve" condition of the plant.

As a system increases in size, however, for a population that requires large daily consumption and higher pressures, due to the construction of taller buildings, there might well be reached a condition where the size of mains and the size of pumps would not need to be greatly increased to furnish fire protection, for they would be virtually large enough to render the combined service necessary with perhaps some slight local lessening of domestic pressure during the fire. Under such a condition it would appear as if almost the only expense of furnishing the fire service on the part of the company would be the placing and maintenance of the fire hydrants, yet the fact that the water system was in place and fire protection given, would, as in the other case named, result in keeping the fire insurance rates at a low figure with consequent great saving to the taxpayers. Some measure of that advantage should inure to the benefit of the water company whose plant makes the saving possible.

There is reason in every problem and to arrive at a just valuation of water service the different conditions must in all fairness be taken into consideration; structural and financial history of the water plant; its operating difficulties, its losses and gains; its replacements, its obsolences; its effect upon the community, whether its investment has made development and general community advance pos-

sible, or whether the community growth made the water plant possible.

A public utility corporation occupies a somewhat different place from ordinary business whose owners can discontinue it, or move it more or less at will.

A public utility is fixed, the capital is locked up and can not be removed; it has united with the community for better or for worse; it is subject to regulatory laws, sometimes oppressive ones; it must meet the whims of local officials it must in general suffer uncomplainingly and keep on spending money whether the return is satisfactory or not. Primarily of course the investment is made with the hope of handsome return, so that if such does not obtain, one may say that it is simply another case of a foolish investment and the owner must take the loss, but it is not an investment where the owners have the control. It rests with the community whether the enterprise be a success, or a failure, consequently the community is virtually a partner and morally must see that fair treatment is given and a fair return is made to those who have invested their hard cash. If the community gains largely as the result of the existence of the plant through low insurance rates, through greater comforts in living and through the easier pursuit of a livelihood, some of that gain should go the utility.

Fire protection payments are usually made as the outward indication of that community responsibility, so that the problem is not only one of establishing precisely the cost of rendering fire protection service, but rather an expression of the proper return from the community as a whole for the service rendered as a whole. This of course is independent of individual payment for water purchased which is personal and should be according to a strict business value of the service rendered.

The case of the Queens County Water Company lies somewhat between the extremes; it is no longer a small plant, nor has it reached the point where it is so large that fire protection factors would be negligible. The peculiar conditions are, as earlier referred to, the non-occupancy of a large territory during a considerable portion of the year; the fire service is rendered throughout the year, while the domestic service largely ceases, for long periods.

The speaker does not agree fully with the proportions which Mr. Goodman has assigned in the borough of Queens for respective domestic and fire service costs. In his judgment the fire protection

factor is a considerably larger one. A comparison of estimated costs of such a system as would furnish adequate domestic supply solely and that which would furnish fire protection and domestic supply both is not a fair criterion alone of the value of its fire protection. Estimates make a good basis for getting at some figures in the case, but beyond them and beyond something allowed for the "ready-to-serve" operations, is the broader moral obligation, to which the speaker has referred; intangible, perhaps, in estimated fixtures but nevertheless worthy and proper to consider, bringing, in the last analysis, settlement of the problem rather along the lines of an equitable trade than a distinctively accounting proposition.

Mr. Morris R. Sherrerd: The last speaker (Mr. Tribus) mentioned that in a municipal plant the fire supply cost was only a question of accounting. There is a little more than simply a question of accounting involved, regarding the proportion charged in book-keeping for fire service even in a municipal plant, since such cost affects the rates for water. In a municipal plant the charge for fire protection should be borne by the real estate, if this is not so then the water taker is paying more than he ought to pay, providing the municipality is carrying the whole expense of fire hydrant maintenance out of its water rent income, and this is done in many municipal plants. Water works managers ought to insist on a direct tax levy to maintain the fire service, and thereby be enabled to reduce the price of water to the water rent payer.

Mr. Charles R. Bettes: Mr. Goodman's paper covers a very important and much neglected matter, i.e., "A fair return for fire service." Only in the last few years has it received other than nominal attention; usually an arbitrary charge has been made depending on policy and conditions, but in no way representing any relation to actual cost of the service rendered.

Mr. Goodman's paper shows a careful consideration of the matter in the right direction. We are quite ready to agree with him in general theory, but not as to the results. Permit us to make clear, at this time, that the estimates from which his conclusions are drawn, except as to operating expenses, are his estimates, as the water company did not submit figures upon cost.

The company's estimate would differ as to reproductive cost and present value of the plant. It would differ, also, as to the proportion

between domestic and fire service; that for fire service being materially increased. It would also differ as to the probable cost of a purely domestic system. Incidentally, it might be mentioned, that for a separate domestic system, an enforced use of equalizing house tanks could properly be considered.

Such tanks would, undoubtedly, add to the original cost but would tend to remove the enormous peak load and thereby effect a saving, not only in original plant outlay, but in its operating expense; thus reducing gross original cost for company and private investment, as well as annual operating expense.

A word as to this peak load, and incidentally as to operating expenses: For over eight months the daily consumption will average less than 2,000,000 gallons daily, ranging from 3,000,000 gallons maximum to 1,000,000 gallons daily minimum; for four months the consumption will average, say 4,500,000 gallons daily with a maximum rate, for a short time, of 14,000,000 gallons daily, and a minimum of 2,000,000 gallons daily. The varying rate demands a large pump reserve and necessitates a pump capacity of 23,000,000 gallons daily for service and 18,000,000 gallons daily for filter. All water is handled twice, to the filter and to final service. It is obvious that lessening of the peak would effect economy, both in original outlay and operating expense.

An objection might be made to Mr. Goodman's scheme in that he failed to fix some system that would automatically take care of additional cost chargeable to fire service on account of new extensions so as to allot the proper charge to fire and domestic service. We are inclined to accept, as covering this point, the recommendation of Mr. Alvord and Mr. Chester as logical and fair, i.e., a certain charge per foot, depending on size of mains. This, of course, to take effect after the initial cost of the service has been established.

Comparing Mr. Goodman's results with those of the Wisconsin Commission, we notice a wide difference. The Wisconsin cases were given very careful consideration by a most competent board, and it is difficult to reconcile such a variance, more especially, when the peculiar local conditions in the present case make the cost of the fire service more expensive and difficult than is the case in any of the plants dealt with by the Wisconsin Commission.

In allotting or apportioning the operating expenses as between fire and domestic service, every effort seems to have been made to make this as fair as possible. The data, however, were based on one year's

expenses; using any other year would of course change the results somewhat one way or another.

The test referred to by Mr. Goodman as made in July was a very fortunate selection. Mr. Goodman, by the way, made the test. The day and hour was one on which draft was at the maximum. For the purpose of showing the dependable conditions under the most unfavorable circumstances, the selection could not have been better. Had all the fire resources in the fifth ward been called into service, less water would have been used, and the fact that there was still a residue pressure of some 10 or 11 pounds would indicate that the supply was ample. Since this test, the fire system has been reinforced by two 16-inch mains and many cross connections, thereby very materially bettering the conditions, and entirely removing any doubt as to the supply for fire purposes.

Mr. Goodman's paper shows skillful and conscientious work for which he deserves the thanks of the association. The paper should attract the attention of water works engineers and should be brought up at the annual convention when it can be open for a more general discussion. The company agrees with his theory and methods. While we do not agree as to the complete justice of his conclusions, we realize fully that in a pioneer case in this part of the country, it was for the interest of the company to have such conclusions most conservative; otherwise political considerations might easily have defeated any change. We do not consider that it would have been good business judgment for us to have contended for all that a scientific distribution of the gross revenue between the public and the private consumers would require.

THE PREVENTION OF WATER WASTE ON RAILROADS

By C. R. Knowles

The past few years have seen much activity on the part of water works engineers towards the prevention of water waste. Many of the large cities have organized special departments to conduct water waste surveys and look after water losses. Unfortunately, with one or two exceptions, this activity has not been felt on railroads, notwithstanding the fact that the railroads are among the largest users of water.

As an example of what may be accomplished by a campaign against water waste, the Illinois Central has reduced the expense for city water alone from $225,112.94 during the fiscal year 1913–14 to $190,438.50 during the fiscal year 1914–15, a reduction in the cost of city water of $34,673.79. This is a net saving accomplished by the elimination of water waste. The expense for city water represents only about 40 per cent of the total cost for water, 60 per cent being for water pumped by company forces, consequently there has been a great reduction in the waste of water pumped by railroad water stations, and a resultant saving that cannot be shown by figures.

Water is generally considered as free as the air we breathe and much of the waste is due to carelessness on the part of employees who fail to realize its cost. It follows that careful instruction, followed by disciplinary measures, where necessary, is the remedy in a campaign to reduce waste. This lack of coöperation due to ignorance of the value of water, sometimes aided and abetted by departmental lines and jealousies, causes thousands of dollars needless expense to the railroads of the country.

American railroads consume daily approximately 1,950,000,000 gallons of water at a daily expense of over $100,000. These figures should be enough to convince almost anyone that water is not free, and that a saving in water is quite as important as a saving in coal, oil or other supplies. It is safe to say that 15 per cent of all the water used by railroads is waste. By waste is meant that quantity of water drawn in excess of the amount actually required.

A few illustrations of the most common forms of waste on railroads will be given, with the cost of such waste and suggested remedies.

Large quantities of water may be wasted in taking water at tanks and penstocks, unless care is exercised to properly spot the engine and avoid overflowing the tender.

Not only does this cause a waste of water but it causes an additional expense for removing ice from track in winter months and repairs to soft track during the summer.

A conservative estimate of the total cost of this waste per annum is $60 per tank. With 30 tanks the annual expense will be $1800, or 5 per cent on $36,000, and will pay the interest and depreciation on the cost of construction of a new 100,000 gallon tank at each station in five years, or will build and maintain a locomotive each year. The remedy is to keep the tank spouts and penstocks in proper repair and compel due care in taking water on locomotives.

One of the most expensive sources of water waste is at engine houses in connection with the use of boiler washout hose and valves. The water used for washing locomotives invariably has to be handled twice to secure the high pressure necessary to properly wash locomotive boilers.

The average cost for such water is in excess of ten cents per thousand gallons. A boiler washout hose with a one inch nozzle at 100-pounds pressure will easily waste 12,000 gallons of water per hour at a cost of $1.20 to $1.50. This does not take into consideration the cost of heating water where hot water is used for washing. This is a very hard matter to control and results cannot be obtained except through the coöperation of the roundhouse force.

Laws prohibiting the use of public drinking cups have made the bubbling drinking fountain a necessity, but the makeshift affairs commonly constructed of half inch to one and one-half inch pipe, and flowing constantly, are an abuse to this system of providing drinking water, and will waste from $150 to $350 per year for each fountain. The actual amount of drinking water required by a man is about one-half gallon per day. A single bubbling fountain with a quarter of an inch opening at 25-pounds pressure will deliver 425 gallons per hour, which would furnish ample drinking water for 10,000 men and allow 50 per cent waste. The only satisfactory way to control this waste is to restrict the size of opening and equip all fixtures of this kind with self-closing valves.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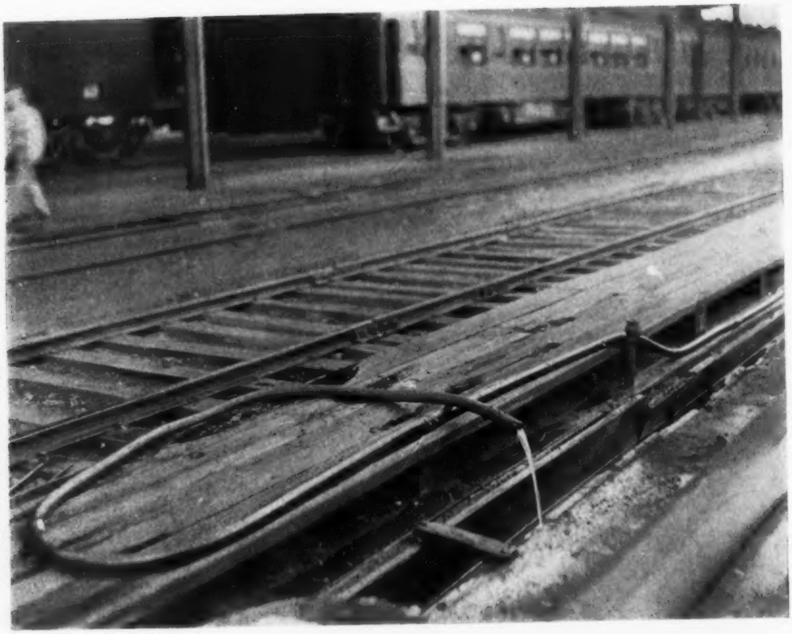
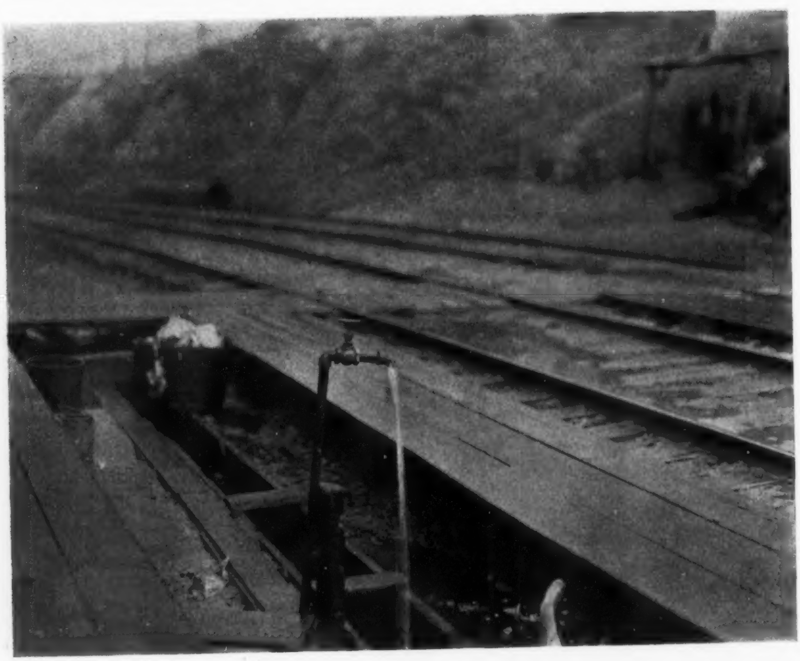




Yard hydrants for sprinkling, filling water jugs and coach yard service also cause a heavy waste of water. A one inch hydrant of this type will waste from 20 to 30 cents worth of water per hour or \$5 to \$7 per day. Forty or fifty of these hydrants are often installed in a single coach yard and as there is nearly always a number of them open and running the loss is enormous.

The improper use of hose for sprinkling, washing coaches, etc., causes a great waste of water that may easily be avoided. To show how water may be wasted in this manner three illustrations are given.

The first shows a hose with open end and is of practically no value for washing or sprinkling as far as efficiency is concerned. The water being wasted and the cost is given in the following table:

One hour, 1,080 gallons @ \$0.10	\$1.08
Ten hours, 10,800 gallons @ \$0.10	10.80
Three hundred hours, 324,000 gallons @ \$0.10	32.40

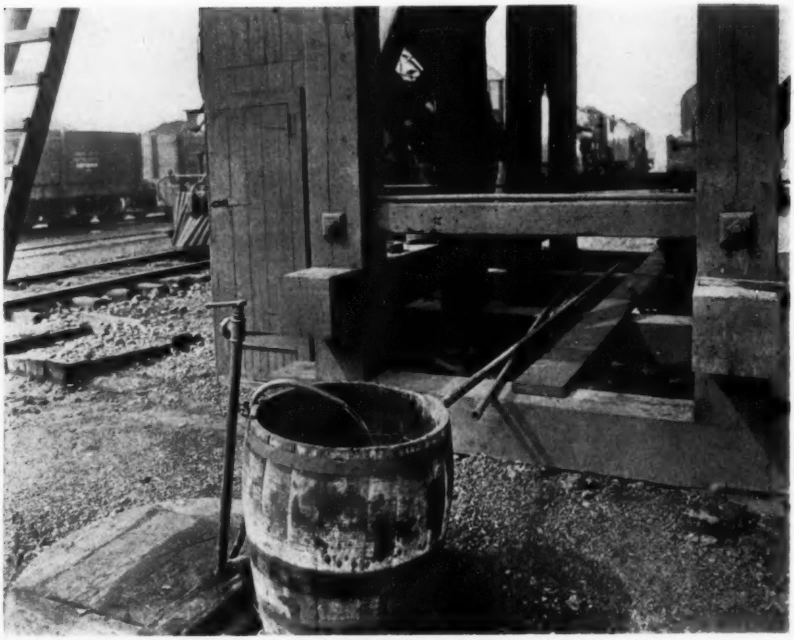
The second illustration shows the hose without nozzle and the stream partially restricted by pressure of the thumb. This stream is probably about 50 per cent efficient and will waste water as follows:

One hour, 540 gallons @ \$0.10	\$0.054
Ten hours, 5,400 gallons @ \$0.10	.54
Three hundred hours, 162,000 gallons @ \$0.10	16.20

The third shows a hose properly equipped with nozzle. This stream is doing the maximum amount of work with the minimum waste of water, the water used being as follows:

One hour, 180 gallons @ \$0.10	\$0.018
Ten hours, 1,800 gallons @ \$0.10	.18
Three hundred hours, 54,000 gallons @ \$0.10	5.40

Leaking or improperly adjusted valves in toilet flush tanks will waste from \$3 to \$50 per month for each battery, depending on the number of fixtures and cost of water. A case was found recently where toilet facilities at a large terminal were causing a loss of over \$400 per month. In another instance the loss was over \$150 per month. The trouble was corrected by cutting down the waste of water, and the saving at these two points alone amounts to \$10,000 per year.



Wash basins, slop sinks and other fixtures connected direct to sewers and drains offer opportunity for heavy water losses, and a saving can be made in almost every instance by giving attention to valves and faucets, keeping them in proper repair and making it a point to see that they are closed when not in use.

Another source of waste is through leaks in underground mains. These underground leaks are not always easy to detect, for there is nothing in the old saying that "leaks will always show at the surface," for if the pipe is laid in a porous formation or near sewers the water finds a ready outlet without reaching the surface. The presence of leaks of this kind may sometimes be determined by use of the aquaphone or sonoscope or by carefully comparing the consumption with the pumpage or meter readings; but locating and repairing the leak are often such difficult matters that one sometimes wonders whether it is cheaper to permit the pipe to leak or make repairs. However, this question is easily answered. It always pays to stop leaks. As an illustration of what may be accomplished by stopping underground leaks, the following figures on the work done along this line in Washington, D. C., in 1910 are taken from the American Water Works Association proceedings of 1911:

	NUMBER	WASTE IN GALLONS PER DAY
Abandoned services and taps leaking	11	305,000
Iron services broken	204	2,438,000
Lead services broken	87	1,202,000
Wiped joints broken	74	710,000
Couplings on services leaking	18	119,000
Curb cocks leaking	30	85,000
Taps blown out	3	50,000
Joints on mains leaking	92	1,034,000
Mains broken	2	332,000
Valves leaking	11	89,000
		6,364,000

This included no leaks or breaks detected by reason of water appearing on the surface of the ground, which goes to prove that watching the surface for underground leakage is a very poor method of locating waste. The great majority of our water mains are underground, and their importance is sometimes lost sight of, but if

they were brought to the surface the realization of their true condition would doubtless prove an instructive but very unpleasant surprise.

The saving effected in handling cinders with modern cinder pit facilities is often destroyed by the waste of water through hose connections. The photograph shows an actual condition. The waste is 10 gallons per minute, 600 gallons per hour, 14,400 gallons per day. The cost is $1.44 per day, $10.08 per week or $524.16 per year.

Fire hydrants are often used for drinking and other purposes with a resultant waste of water. The illustration shows a condition by no means uncommon. One hundred gallons of water are being wasted to secure perhaps a pint of water. Serving drinking water, to say twenty men, by this expensive method would cost as follows: A man will require water from four to eight times per day of ten hours or an average of six times per day, thus twenty men who drink 120 times a day using this method of securing their drinking water will waste 12,000 gallons while drinking 5 gallons.

A faucet may be noticed to leak, but no effort is made to close the faucet or repair the leak, for the reason that the possibility for loss is not realized. The first picture shows water leaking drop by drop:

15 gallons per day, cost @ $0.10	$0.0015
105 gallons per week, cost @ $0.10	0.015
5,475 gallons per year, cost @ $0.10	0.5475

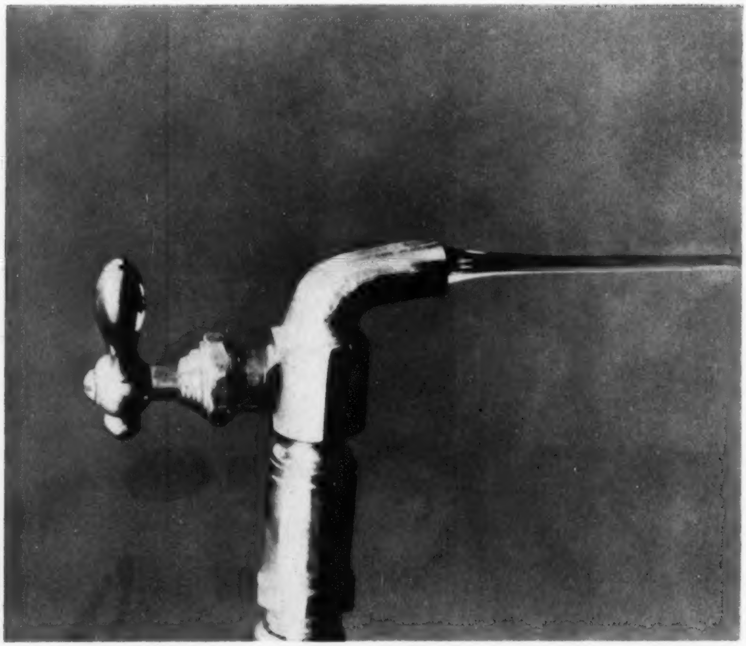
The second picture shows water leaking through a one-fourth inch opening:

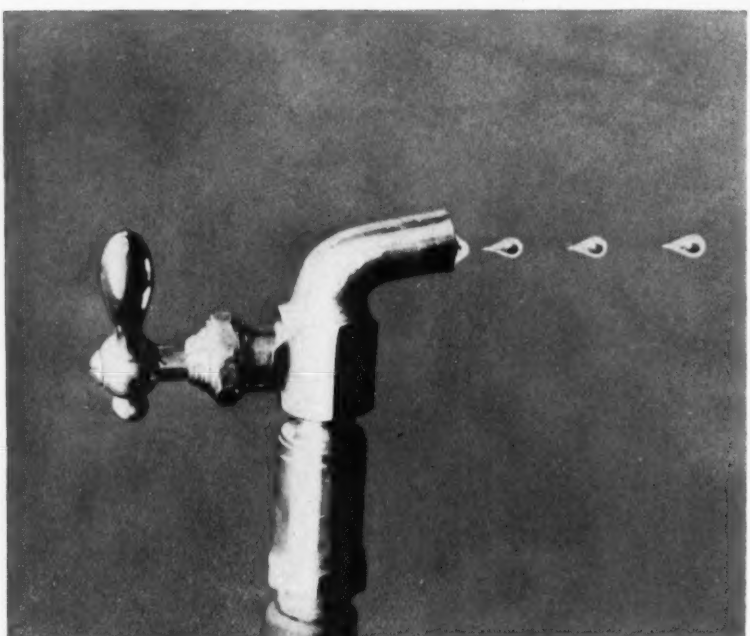
13,435 gallons per day, cost @ $0.10	$1.34
94,045 gallons per week, cost @ $0.10	9.40
4,890,340 gallons per year, cost @ $0.10	489.03

The third picture shows water leaking through a one-half inch opening:

53,568 gallons per day, cost @ $0.10	$5.35
374,976 gallons per week, cost @ $0.10	37.49
19,498,752 gallons per year, cost @ $0.10	1,948.75

The rate used in computing the cost of city water is $0.10 per thousand gallons, which would probably represent the minimum





rather than the average rate as paid for city water. In computing the cost of water in over three hundred cities throughout the United States, the maximum cost, where water was furnished by private companies or municipal plant, was \$0.23 per thousand gallons, while

the minimum rate was \$0.09, making an average rate of \$0.16 per thousand gallons, the rate in a number of the cities being as high as \$0.50 per thousand gallons.

Thus it will be seen that the saving as given is very conservative.

TROPICAL WATER SUPPLIES, WITH SPECIAL REFERENCE TO THE CANAL ZONE AND TO VERA CRUZ, MEXICO[1]

By James T. B. Bowles[2]

In writing this paper it was not the writer's idea to go into details concerning these water supplies, but to give their development in outline.

Many years ago, when the Nicaraguan Canal was proposed, Surgeon-General Sternberg discussed the municipal water supplies of Nicaragua, and placed much stress upon its great importance.

Later, before the American régime, when General Gorgas made his first sanitary survey of the Canal Zone, Major Gillette, then captain in the engineering corps of the army, accompanied him and reported upon the possible sources for water supplies.

It was recommended that at least part of the water supplies should be obtained from driven wells. But it was soon discovered that sufficient water could not be thus obtained and it was necessary to look elsewhere for water.

During the early days of the American occupation, the installation of an adequate and uncontaminated water supply was the all important point. At such a time, with a great scarcity of material and at a great distance from supply depots in the United States, and often when a piece of pipe was ordered, a wheelbarrow or shovel was sent, no time or thought could be given to the design of elaborate and fancy water supply systems. The all important point was to obtain some kind of a pipeborne water supply. Little did it matter then whether or not the joint was perfectly smooth, or whether the pipes were of the same kind, and in some cases they were of different sizes, all were jointed together in some way. It was this water supply which saved the day, as it was not until a pipeborne

[1] Read at meeting of Four States Section, Philadelphia, January 18, 1916.

[2] Assistant director Bacteriological Department, Lederle Laboratories, New York City; formerly physiologist of Canal Zone water supplies, and sanitary expert with expeditionary forces at Vera Cruz, Mexico.

water supply was installed that yellow fever was entirely eradicated. In fact, the writer thinks that General Gorgas considers the installation of the pipeborne water supply the most important means in doing away with yellow fever.

It is most interesting to see how this original water supply has been developed into what now might be called the most efficient and the most modern system of water purification in Central or South America.

Speaking in general, the water supply for the cities of Panama and Colon, and the small villages along the line of the Panama Railroad, consisted of small impounded streams forming reservoirs. In some cases the Chagres River or tributaries of it were used, and wherever this was done the towns and villages were furnished with condensed water for drinking purposes.

Starting from the Atlantic side, and going toward the Pacific, there was in the beginning the old Panama Railroad reservoir back of Monkey Hill. Its water was used to supply the Panama Railroad and a few buildings in Colon. Water was sold from barrels and stations. In 1906 the Brazos Brook Reservoir with a capacity of 640,000,000 gallons was completed. It supplied the cities of Colon and Cristobal. The water from this reservoir was practically surface and rain water caught during the rainy season, and held for use during the dry season. At certain times of the year, the water had quite a distinct odor and color, but was practically free from any contamination, as the watershed was entirely policed. A few years later pressure filters were installed, and after that a sedimentation basin, and the water was treated with aluminum sulphate.

Gatun originally obtained its water from the Chagres River, and condensed water was distributed among the houses. Later in 1910, Agua Clara Reservoir with a capacity of 600,000,000 gallons was constructed. Two years later a mechanical gravity filter plant was constructed with a capacity of 2,500,000 gallons per day, when running at the rate of 125,000,000 gallons per acre per day.

Carabali Reservoir, constructed in 1906, with a capacity of 160-000,000 gallons, supplied the town of Gorgona. There was always more or less trouble from algae growths in all the reservoirs, but Carabali gave the most trouble. However, it responded very readily to the copper sulphate treatment.

Camacho Reservoir, constructed in 1907, with a capacity of

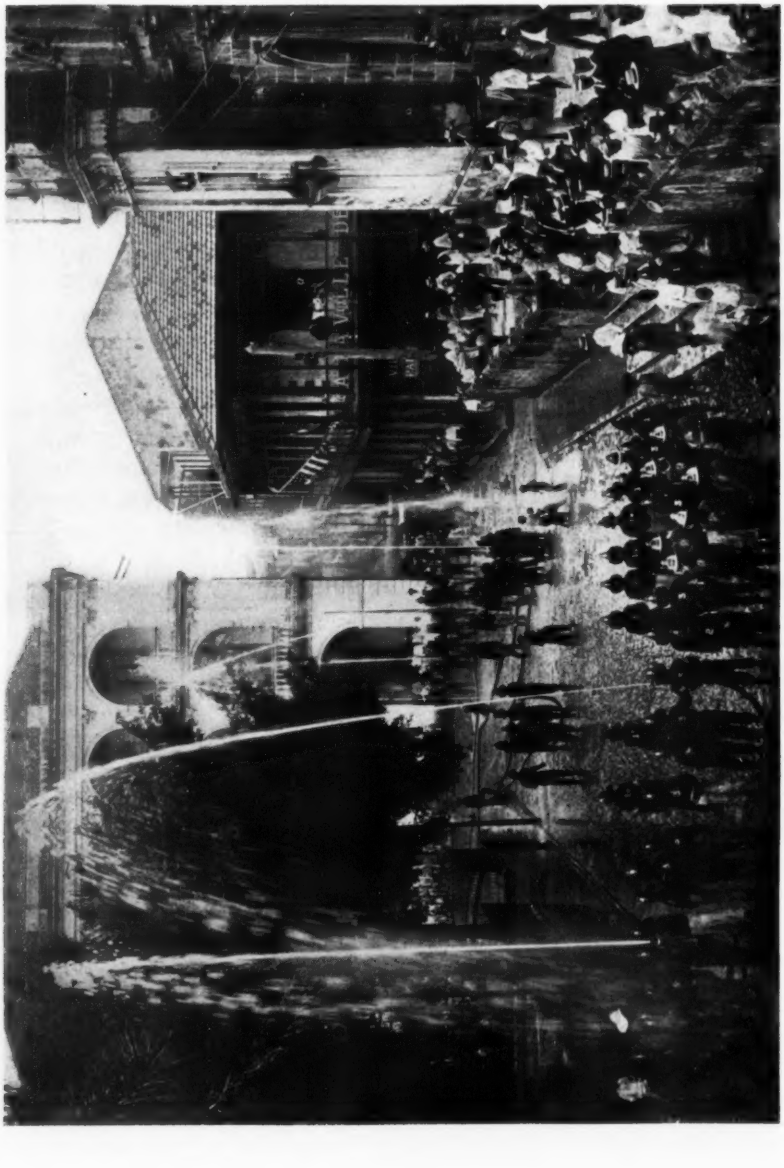


FIG. 1. INSTALLATION OF PIPE-BORNE WATER SUPPLY BY THE AMERICANS IN PANAMA CITY

375,000,000 gallons, supplied the town of Empire. This reservoir gave the least trouble of any in regard to tastes and odors.

Rio Grande, constructed in 1906, with a capacity of 487,000,000 gallons, supplied the towns of Culebra and Ancon. This water was low in bacteria, but at times had bad odors and tastes. At Ancon the water was filtered by pressure filters without use of a sedimentation basin.

Cocoli Lake was a temporary auxiliary supply for Culebra and Ancon.

The above is a description of the water supply as it existed during most of the construction period. It was constructed with no particular idea to permanence, but with an idea of taking care of the immediate use. It answered the purpose well, and served to prevent many waterborne diseases.

The building of the modern filtration plant at Gatun was the beginning of the permanent water supply system for the Panama Canal.

There was always a great lack of water for Colon and Cristobal. This led to the building at Mt. Hope of a new mechanical rapid gravity filtration plant having a capacity of 7,500,000 gallons per day designed by Mr. George M. Wells, Resident Engineer.

Brazos Brook Reservoir was still to be used, but its capacity was increased by digging a tunnel into Gatun Lake. At a certain portion of the upper end of Brazos Brook, only 500 feet from the upper end of Gatun Lake, the two lakes were connected at elevation +75. A gate house at the tunnel controls the flow by a float valve, keeping Brazos Brook always at the same level. The water flows by gravity from the reservoir to Mt. Hope filtration plant, where it enters an aeration chamber through bronze nozzles arranged to give a fine spray. It next passes through a mixing chamber where it receives an automatically controlled dose of aluminum sulphate. After being thoroughly mixed it flows through the sedimentation basins to the filters, and is pumped from the clear water well, which is beneath the filters, to the city. Electrically driven pumps are now being used at all stations.

The typhoid fever rate has always been exceptionally low, practically nil. At two different times there were a few cases. Once the cause was a carrier, and once the cause was oysters from Panama Bay. There was no spread of the disease. The dysentery rate was always low, exceptionally low for a tropical country.

In 1912, General Goethals appointed a committee, consisting of Admiral Rousseau, Mr. G. M. Wells, Mr. Cole and the writer, to make a study, and to locate sites and to submit plans for a permanent water supply for the towns south of Pedro Miguel, including the cities of Panama, Ancon and Balboa. A thorough study was made of all possible sources after an estimate had been made of the probable amount of water that would be needed per day for all of these towns, taking into consideration the adjustment of the cities and their growth after the Canal was completed. It was finally de-

FIG. 2. THE NEW MIRAFLORES FILTRATION PLANT WHICH FILTERS THE WATER FOR PANAMA CITY, AND OTHER CITIES ON THE SOUTHERN SIDE OF THE ISTHMUS

cided to use the small lake at Miraflores, east of the Panama Railroad. This lake was fed by the two rivers, Caimatilla and Caimeron. It was connected with the main Miraflores Lake by a culvert under the railroad. In times of dry weather there would not be enough flow from the rivers to prevent the Miraflores Lake from backing up into the small lake. The committee did not like this, feeling sure that Miraflores Lake would increase in salt content on account of the lockages, and thinking that it would give trouble by raising the chlorine content of the water supply. In the report to the chairman

and chief engineer, the question of contamination from salt water was brought to his attention. As an alternative it was suggested, if the Miraflores water could not be used, that the water be obtained from the Chagres River at Gamboa, at some point up the river where there would always be a current.

The chief engineer felt that that point had been considered previously by the canal engineers, that they had decided that there would be no special increase in the chlorine content, and therefore he felt that the water supply would not be affected by salt water. Work was started at Miraflores, and Mr. G. M. Wells was appointed to design the entire plant.

The plan was to have a pumping station at the lake east of the Panama Railroad. The water was to be pumped to a mechanical gravity filter plant on Miraflores hill, a short distance away. The capacity of this plant is 15,000,000 gallons per twenty-four hours, running at the rate of 125,000,000 gallons per acre per day. The water is pumped to an aeration basin which contains nozzles arranged to give a very fine spray in order to aerate the water as much as possible. From the aeration basin the water passes through the head house, where it receives a dose of aluminum sulphate, and after being thoroughly mixed by passing over and under a series of baffles, the water flows into the sedimentation basin, which is very long and well baffled so that the water has sufficient resting period before it flows onto the filters.

At the Miraflores filtration plant there is uniformity in the distribution of wash water and rate of filtration, low maintenance cost and a minimum of strainer trouble and loss of sand. This had been brought about by incorporating as the main feature of the design of the underdrainage system a false bottom or pressure chamber in place of the usual ridge block and pipe systems. Water under a pressure of 28 pounds per square inch is carried into the filters through feed pipes with their upper ends deflected 180 degrees so that the flow of wash water is deflected downward upon the filter floor or gravel bed. These feed pipes have been fitted with strainers, but test results have shown that in this type of underdrainage system strainers are unnecessary.

CHARACTER OF THE WATER

Under ordinary conditions the turbidity of the raw water is low, but after heavy rains on the watershed of the river it is increased to a few hundred parts per million.

AERATION

On account of decided odors intermittently present the raw water is first discharged into an aeration basin through 105 nozzles, which are arranged in seven batteries of 15 each. During the months of April, May and June, 1915, the dissolved oxygen in the raw water was increased from an average of 55.8 to 88.7 per cent of saturation. During the same period the free carbonic acid was reduced from an average of 2.6 to 0.5 parts per million.

The aerated water flows over three weirs into the three concrete mixing chambers located in the basin of the head house. The alum solution is added to the aerated water as it enters the first compartment of the mixing chamber. During the months of April, May and June, 1915, the alum averaged 192 pounds per million gallons, varying from a minimum of 101 to a maximum of 471 pounds per million gallons.

From the mixing chamber the water passes into three crossconnected parallel concrete sedimentation basins; the length of each basin is 300 feet. The combined width of the three basins is 125 feet. The depth of the floor valleys is 17.75 feet. At the present time an average sedimentation period of twelve hours is obtained.

Each basin is divided into three compartments by two pressure baffle walls. Extending across these baffle walls in front of the openings there are concrete skimming troughs which reach to within about a foot of the normal water level. Between the pressure walls there are two light baffle walls which contain four openings, 6 feet wide extending from within 2½ feet of the top to 3 feet from the bottom of the basin. In addition to the baffling effect they prevent wave action which would otherwise result, from the strong wind which prevails at certain times. All valves are hydraulicly operated, controlled from an operating table located in the head house.

CONSTRUCTION OF FILTERS

The fourteen rapid sand gravity filters are constructed of reinforced concrete, and measure 19.75 by 21.5 feet, and 11 feet deep to the floor, in which the underdrainage system is placed. Each unit has a sand area of 425 square feet.

Thirty inches of Chame sand, with an average effective size and uniformity coefficient of 0.4 and 1.9 respectively, and 2 inches of Chagres River gravel, arranged in three layers, comprise the filtering medium. An independent air system, to be used only in case hard spots and mud patches develop, is placed between the small and medium grades of gravel.

When a filter is washed at a rate of 15 gallons per square foot of sand surface, equivalent to a 24-inch rise of wash water per minute, a pressure of about 16 pounds per square inch is developed on the false bottom, and the sand bed is raised $8\frac{1}{4}$ inches above its normal elevation.

It is true that false bottoms have been used in filters built prior to these, but they have been designed for low pressures and rates of flow of wash water. As far as the writer knows these filters are the only ones embodying concrete false bottoms which will withstand a maximum pressure of 28 pounds per square inch and will allow a vertical rise of wash water of 2 feet per minute with an ample margin of safety.

Starting March 15, during the first ten days of operation, the percentage of wash water averaged 8.8, but dropped to 2.35 the remaining seven days of the month.

During the early part of the construction work of the plant the writer carried on a very elaborate survey of the chlorine content of the water. Regular stations were made from the sea side of Miraflores Locks, through the locks, into Miraflores Lake, through the channel and on either side of the channel, through Pedro Miguel Locks, a short distance into Culebra Cut, then from Miraflores Lake, through the culvert under the Panama Railroad, to six or eight stations distributed over the small lake on the east side of Panama Railroad, and to one station at the proposed intake in this lake.

At first, lockages were made from both ways into Miraflores Lake, then Miraflores Lake was lowered 10 feet, then raised to normal elevation, samples being taken before and after these movements. Then samples were taken twice a week at the regular stations as

named above for several months. The result showed a gradual increase in the chlorine content. Owing to the fact that Rio Grande Reservoir could not supply enough water it was necessary to establish a temporary pumping station in the proposed lake at once. This water was treated with hypochlorite before it entered the mains, and was afterwards filtered in Ancon through the old pressure filters. When the chlorine content of the water reached 65 or 70 parts per million, much trouble was had with the boilers at the Miraflores Power Plant.

After these results from the high chlorine content were obtained, the Chief Engineer decided to use the Chagres River water. Of course this change made unnecessary the proposed new pumping station at the lake east of the Panama Railroad at Miraflores. Fortunately, the construction of this station had only been just started, so there was no great loss. Going to the Chagres River meant the laying of a pipe line 9 miles long. There was no change in the location of the filter plant, as the point chosen was the logical situation for it. It was necessary temporarily to extend a pipe line into the "Cut" just beyond Pedro Miguel locks in order to obtain water to dilute the old supply which was high in chlorine.

After filtration, the water passes through a Venturi meter, where it receives a dose of hypochlorite of lime. Liquid chlorine is being installed. Excellent water, and plenty of it, is now being furnished by the finest filtration plant in South or Central America. Its location is very unique, as it overlooks on one side, Culebra Cut, Pedro Miguel and Miraflores Locks, and on the other side, Panama and Balboa Bay.

With the new filtration plants at Mt. Hope and at Gatun, and the newly completed plant at Miraflores, the water supply question of the Canal Zone and the cities of Panama and Colon ought to be settled for many years to come.

WATER SUPPLY OF VERA CRUZ, MEXICO

There are two water supply systems for Vera Cruz. The main supply coming from the Jamapa River and filtered at Tejar is used everywhere. The other supply coming from the swampy region at Legarto supplies the Terminal Company exclusively for railroad work and washing purposes.

The water works plant at Tejar was installed by Pearson and Company, Ltd., in 1904. The water flows by gravity from the Jamapa River into a receiving well, from which it is pumped into a

small reservoir and from which it flows by gravity into a sedimentation basin having about four hours of rest. After passing through the sedimentation basin the settled water flows by gravity to four slow sand filter beds, the filtered water flows into a receiving well and then into a sump.

The water is pumped from the sump through a 15-inch and a 10-inch main into the distributing reservoir at Los Cocos. From this distributing reservoir, the water flows by gravity through a 20-inch main to Vera Cruz. The water plant has a capacity of 2,000,000 gallons per day, which is not sufficient for Vera Cruz.

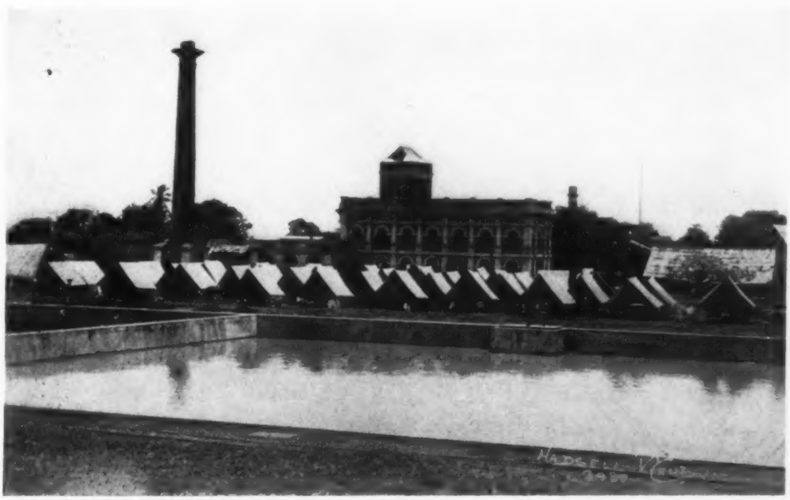


FIG. 3. ENCAMPMENT AT TEJAR, VERA CRUZ

In order to economize in the use of water, the supply is turned off from a part of the city for certain periods of the day and night, thus allowing the head to increase in the distributing reservoir at Los Cocos.

The inhabitants protect themselves during the time that the water is shut off by providing tanks on the roofs of their houses. These tanks are connected with the main supply by a float valve so that when the tank is full the city pressure is shut off.

An apparatus for putting chlorine in the filtered water was installed and ready to be used if the water became bad. But it was not necessary to use the chlorine in the water as very good results

were obtained from the filters. Both chemical and bacteriological control analyses of the water were made in the Field Hospital Laboratory. The analysis of raw water showed gas in 1 cc., 0.5 cc., $\frac{1}{10}$ cc. samples in lactose broth and 4000 or 5000 bacteria per cubic centimeter on agar plates. The filtered water showed no gas in 1 cc., 0.5 cc., $\frac{1}{10}$ cc. samples in lactose broth and generally less than 50 bacteria per cubic centimeter on agar plates.

In order to increase the water supply, surveys were made and it was found that the present supply could be increased at least 45 per cent by installing a booster pump to raise the water into Los Cocos reservoir, thereby relieving the pressure on the line and allowing both pumps at Tejar to be used. This scheme was recommended and accepted, with the idea that the pump would be purchased as soon as the city had the money.

DISCUSSION

Mr. J. M. Goodell: It is only fair to the gentleman who has just been elected the first chairman of the Four States Section to say that the first water works built on any considerable scale in the Canal Zone by Americans were constructed under his direction. At the outset of our canal work conditions were very different from the well ordered efficiency of later days.

Mr. Davis had to find his construction plant in the jungle, where it had been left by the French. He had to train his Jamaica negroes, and those from Antigua, Martinique, Hayti and the other supply points for labor, to work in ways wholly unfamiliar and wholly abhorent to them. All this had to be done when disease was rampant, before the swamps were drained, the houses screened, the grass cut and the Zone made fit for a white man to live in.

The fight which Mr. Davis made there, against an enervating climate, insanitary surroundings, slack and unskilled labor, and the tangles of government red tape due to all details being then threaded through the main canal office in Washington, set a pace for achievement which formed one of the best stories of the Canal Zone. It was gratifying to learn from the author of this paper that General Gorgas considered the improved water supply at Panama so important in the conquest of the insanitary conditions there, and it is still more gratifying to be able to introduce to you the engineer who has all the credit for the achievement.

PUMPING MACHINERY

TEST DUTY VS. OPERATING RESULTS

By J. N. Chester

This paper is the result of an effort prompted by a request from our Secretary starting with the statement that "we now install pumping engines of 200,000,000 foot pounds guaranteed duty, but get much less every day efficiency," and ending with the admonition that we "dwell on what the coal piles should give us in water pumped."

History relates that over 2000 years ago, one Alexander the Great wept because there were no more worlds to conquer. This being the case, we are quite sure that Alec up to that time at least, had never looked into the possibilities of steam plant efficiency.

From physics we learn that heat and energy, or work, are equivalent and mutually convertible one to the other. Our pump station results represent work. The source of the heat to perform this work is coal, and the means for converting the heat of the coal into work is our steam plant equipment. The per cent of the heat contained in the coal that may be realized in useful work or energy, represented by the water delivered into our mains, and why the losses is the problem before us.

The coal we buy contains, we will say, 100 per cent of heat, not that coals do not differ in heat producing or thermal values, but let us assume that the coal we have contains heat represented by 100 per cent, then to those familiar with the subject, it is well known that with the contrivances in use to this date, we have been able to make apparent in work done as represented by the water column delivered with the most efficient machines, less than 20 per cent of the 100 per cent of heat in the coal fired under our boilers and in many instances, the net result does not exceed 5 per cent. Why this loss?

In the boilers, due to the heat that must necessarily pass out through the stack so that the temperatures of the hot gases in the boilers may be in excess of the temperature of the steam generated

and thus effective throughout their entire travel through the boiler, coupled with the radiation of the exterior parts of the boiler and the incomplete combustion of fuel represented by the combustible matter remaining in the ash, test boiler efficiencies are not obtained greatly in excess of 70 per cent, or otherwise stated, we realize only in net heat delivered as dry steam from the boiler, 70 per cent of the total heat contained in the coal, which we termed 100 per cent.

Next comes the steam lines and be they long or short, properly or poorly proportioned, bare or well covered, some radiation must take place, and some loss due to friction must be further incurred, for friction represents energy and energy is heat and so, under the best of conditions, we can expect to deliver less than 70 per cent of heat of the coal converted into steam and less than 70 per cent at the engine throttle.

Then due to the ineffective utilization of the heat delivered at the throttle by the highest grade steam motors or engines in use today, which seldom exceeds 20 per cent, we find the net results left of our original 100 per cent in the coal approximately 15 per cent.

As a concrete illustration of the above, recent final and preliminary duty and efficiency tests at Erie, Pennsylvania, showed that of the available heat units determined by analysis of the coal fired, the boilers delivered at their outlet nozzles 71 per cent, and of the available heat units received by the steam pipe at the discharge nozzle of the boilers it delivered to the throttle at the engine 99.6 per cent; and that the engine converted into useful work but 21.5 per cent of the available heat units delivered at its throttle by the steam pipe, or that the entire combination, not considering auxiliaries of any sort, showed an overall efficiency of 15.25 per cent, and still the engine on preliminary test (final test not yet run) performed a duty of 205,348,000 foot pounds for each 1000 pounds of steam consumed.

But probably, to be more readily understood by the water works operator, we would better restate this problem in the terms of the relations between test duties based on 1000 pounds of dry steam and obtained on tests for acceptance as compared with every day operating results per 100 pounds of coal fired under the boilers.

Before getting too deeply in either discussion, let it be known that we have accorded the field of plants consuming one million and less to the internal combustion engine and electric motor driven pump.

For pumping units on which the demand is 1,000,000 gallons or

more daily, practical test duties vary from 50,000,000 to 200,000,000 foot pounds of useful work performed for each 1000 pounds of dry steam delivered to such unit.

For the same machines, the station duty would be expected to vary from 20,000,000 to 125,000,000 foot pounds of work done for each 100 pounds of coal fired under the boilers.

Why the difference between the maximum steam duty of 200,000,000 and the coal duty of 125,000,000? Also the minimum steam duty of 50,000,000 and the minimum coal duty of 20,000,000?

Pump station results, as most of us know, are affected by the following:

1. Quality of coal.
2. Efficiency of boilers.
3. Efficiency of steam lines.
4. Station capacity.
5. Head against which water is delivered.
6. Load factor.
7. Adaptability of machinery.
8. Compactness of station.
9. Low vacuum in condensing units.
10. Care in operation and many other minor elements.

For easy handling, let us take the case of a station in which the major unit is capable, when in service, of pumping all the water demanded and whose test duty was one hundred million foot pounds per 1000 pounds of dry steam delivered to it, and endeavor to make clear the differences between steam and coal duty.

Naturally, if each pound of coal fired under the boiler would evaporate into steam, at the pressure desired, ten pounds of water and none of this steam became condensed in the channels conveying it to the engine, then there would be no difference between coal duty and steam duty. Unfortunately, this is not the case.

In the average water works station with the best coal, Pennsylvania or West Virginia product, we are able to obtain but an average of about 8 pounds of water evaporated per pound of coal burned. Consequently, if nothing more than this existed, our steam duty of 100,000,000 would be reduced to 80,000,000 in station duty. Besides, we cannot all locate our stations within a practical shipping distance from the Pennslyvania or West Virginia coal fields, and those who obtain their coal from the Ohio districts must expect about 7 pounds of water per pound of coal, and from the Illinois

and Indiana districts, in the neighborhood of 6 pounds of water per pound of coal, so that the latter has reduced the 100,000,000 duty to 60,000,000 duty without further inroads. So much for the quality of coal.

The above evaporative results are based on the ordinary boiler efficiency of about 65 per cent, which calls for intelligent firing, the boiler operating, within at least 80 per cent of its rated capacity, grates that will prevent there remaining in the ash more than 5 per cent combustible, a stack draft that will supply the coal being consumed with the necessary amount of air, boiler walls sufficiently tight to prevent the admission of air above and beyond the grates in quantities that will interfere with the best combustion, and the whole exterior of such a construction as to provide an insulation that will keep down the loss of heat by radiation to the minimum.

Unfortunately, the above are seldom found in the ordinary small water works plant in a combination that provides a boiler efficiency greatly in excess of 50 per cent, and efficiencies running as low as 40 per cent are frequently found, so in the latter case, even when firing a coal from which a high evaporation might be expected, a much lower net result is obtained.

Much more may depend upon whether the steam lines are well proportioned, for if too large and the velocity sluggish, the condensation will be increased. If too small, a portion of the heat must be lost in friction. If bare, a large amount of useful energy escapes through radiation, and in 90 per cent of our steam plants the covering has been done to no specifications other than the will of the company manufacturing and installing such commodities, wherein the covering generally stops short of flanges or fittings about 2 inches on each side, seldom fits the pipe tight, and in consequence, is but 50 per cent as efficient as though it were continuous over fittings and provided against air circulating between the covering and the steam pipe. A 10 per cent loss of energy between boilers and engines is not an uncommon one, when by proper care in design and construction it can be kept within 1 per cent.

The next great loss comes from a source which has been frequently referred to in the meetings of this association, and while many of the pump and boiler builders think it is a hobby, yet you may be assured it exists in 90 per cent of our plants in stern reality. It is the varying demand and head and consequent load factor of

the plant, and it is not a matter that either the designing engineer or the operating officials can correct. Metering intensifies it, so even when brought to the minimum, it still remains a large factor, causing inroads on economy; for though the water may be pumped once and then to a reservoir, a well selected engine should, at the time it is purchased, exceed in capacity the demands to be made upon it, and although when operated the reservoir may permit it to deliver at its rated capacity while in operation and thus the maximum of economy from this standpoint obtained, it must, a portion of its time, be either shut down or operated below rated capacity, and so subject its economical possibilities to the inroads of the fixed thermal charges that continue whether the pump is in operation at full or half speed.

With 75 per cent of our water works plants there exists no high level reservoir and, consequently, the delivery of the pump is governed by the demand on the mains, which varies throughout the twenty-four hours in the ratio of its extremes of about one to three.

Then again, in many plants having a capacity of less than 10,000,000 gallons daily, fire service is rendered by direct pressure, which calls for an increase when the alarm comes in of from twenty to sometimes 100 per cent, for all of which the boiler power must be kept in constant readiness, thus increasing grossly the fixed thermal losses necessarily to be charged against the station's efficiency.

When an engine is tested for acceptance and to prove the builder's guarantee of efficiency, we unfortunately too often set up in the purchaser's mind a standard which he hopes to but never in the future realizes, not only for the reasons above discussed, but others to follow, one of which is that during this duty test, we simply measure the steam used by the engine, neglecting, of course, that used by many of the auxiliaries such as the feed pump, the electric light engine now to be found in a majority of stations, sometimes the blowing engine that produces the draft, and frequently the air compressor that charges the chambers, the heating of the station and frequently adjacent buildings, all of which may represent a draft on the boilers from ten to 100 per cent of that of the main engine.

As an example of the above, extracts from an analysis made by a university professor and his class of a pumping plant in Pennsylvania where one pump in operation did all the work and was ordi-

narily run at full capacity, the following distribution of steam generated was ascertained:

	Per cent
Consumed by main engine	60.45
Consumed by air pump	16.20
Consumed by lighting unit	4.20
Consumed by Holley vent to atmosphere	6.62
Consumed by drains, heating coils, etc	5.47
Consumed by Holley return and engine jackets	7.06
Total	100.00

The boilers were fed from the pressure in the discharge mains.

The writer, some years ago, during an engine test at Jamestown, New York, measured the water into the boilers and from the discharge of the air pump of the main engine which, aside from the feed pump in the boiler room, and a steam jet employed to eject the condensate from the dry well was the only steam consuming element in operation other than that steam was being supplied to the jackets of two idle engines in order to keep the station warm, the temperature outside being sixteen below zero, and the final results showed the water discharged from the air pump and jackets from the main engine was but a trifle over 50 per cent of the total fed during the period of the test to the boilers.

In recent years, due to our constantly increasing population and consequent congested districts with modern sanitary methods, the majority of our water supplies, to be safe, must be filtered, and the installation of purification plants unfortunately generally necessitates the water being pumped from the source to the filters and again repumped to the mains whence the consumption is drawn. Notwithstanding this, that individual, to whom the man immediately responsible for the economy of this station must report, forgets this fact and is prone to demand, as a station duty, the test duty of but what may be termed the high service unit, ignoring all of the elements enumerated above and which must necessarily make inroads on the station's efficiency.

There is too great a tendency on the part of the station or operating engineer to neglect or disregard his means for removing the back pressure from the exhaust side of the low pressure piston in his engines, otherwise known as his condenser and air pump or vacuum producing facilities, for with even reciprocating engines, nothing less than 26 inches, as indicated by the mercury column, should

be tolerated, while unexpected visits generally find in the neighborhood of 20 inches.

The loss due to low vacuum may be roughly reckoned in reciprocating engines at 1 per cent for each inch of mercury. Steam turbines require, for economical operation, a much greater vacuum than 26, and while the condensing facilities may be nursed at the time of the test to produce the desired results, the greater is the fall when the lower vacuum of every day results becomes effective.

Taking up the last of the major elements that tend to reduce plant efficiency, we come to what is too frequently found, to wit: the inadaptability of many of the steam producing, pumping and auxiliary units due many times, to be sure, to changes that have taken place that are beyond the control of those responsible for their presence, but often, to the exercise of bad judgment, or none at all, in their original selection and installation, arising mainly from an unwillingness to incur expense of expert advice in the selection of same and a proneness to permit manufacturers to make the final recommendation.

This reference to manufacturers must not be construed by them as too great a reflection upon their ability to act in such capacity, but from the writer's own experience which reoccurs nearly every time a new station is to be built or an old one to be rebuilt, when, first, the individual with electric current to sell appears, and many times accompanied by another with an electrically driven pump to dispose of, and endeavors to convince him that electrically driven pumping machinery, regardless of conditions of service, is the only kind that will properly meet the situation; then comes the steam turbine driven centrifugal advocate followed naturally by the builders of the several different types of reciprocating machinery, all of whom thoroughly believe and earnestly insist that what they have to offer is what the conditions at hand demand, and only a simpering idiot would select anything else, and so the individual, whose experience is limited to the operation of but one plant, too frequently falls a victim to the wiles of the overzealous and inconsistent salesman.

To conclude this paper with something tangible as a representation of the general conclusions of what we have hereinbefore discussed, the writer has prepared diagrams which at least, in a general way, indicate what, under certain circumstances, we have reasons to expect.

In figure 1, is plotted graphically the cost of energy to pump

1,000,000 gallons of water both by steam and electricity against 100 pounds gross head with electrical machines having efficiencies varying from 30 to 80 per cent current costing \$0.1 per K.W. hour and with steam machines producing a station duty varying from 20,000,000 to 200,000,000 foot pounds duty per 100 pounds coal burned under the boilers and with coal at one dollar per ton, and from this diagram, those interested may readily obtain the energy cost at any efficiency of electrical unit, or duty of steam unit, and at any cost of current or coal by one simple multiplication, and in using this diagram, don't be too optimistic regarding either efficiency or duty.

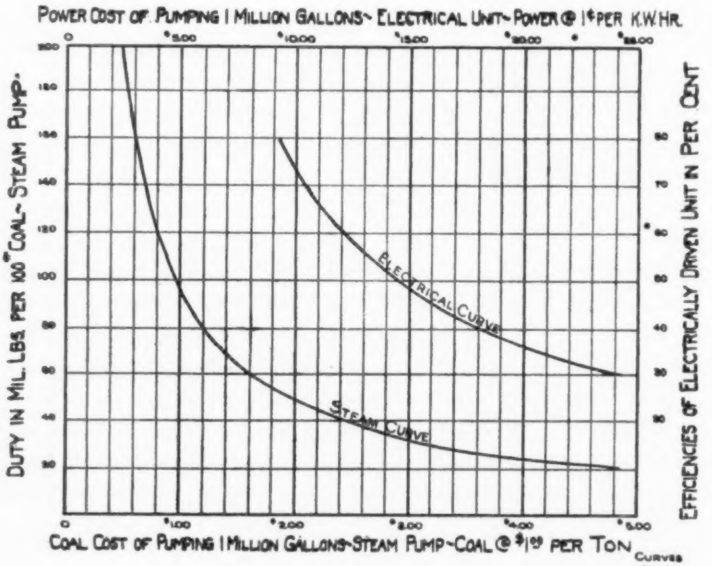


FIG. 1

CURVES showing COST OF PUMPING WATER against a PRESSURE OF 100 LBS. PER SQUARE INCH

Figure 2 is of the same nature as figure 1, except that it is so prepared as to be more applicable to low service or filter pump work, the head being assumed at 50 feet instead of 100 pounds as in figure 1.

The diagrams represent actual results that may be obtained under the conditions given and their intelligent use may prevent water works operators from being lured into the use of electricity under

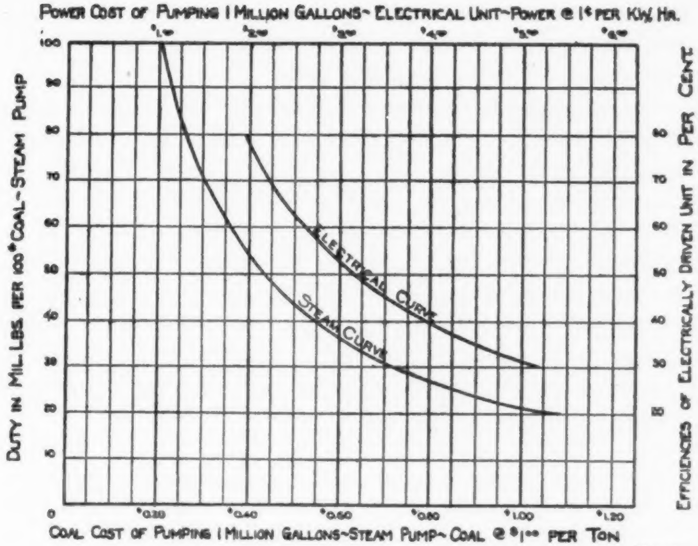


FIG. 2

Curves showing
Cost of Pumping Water
against a
Head of 50 Feet

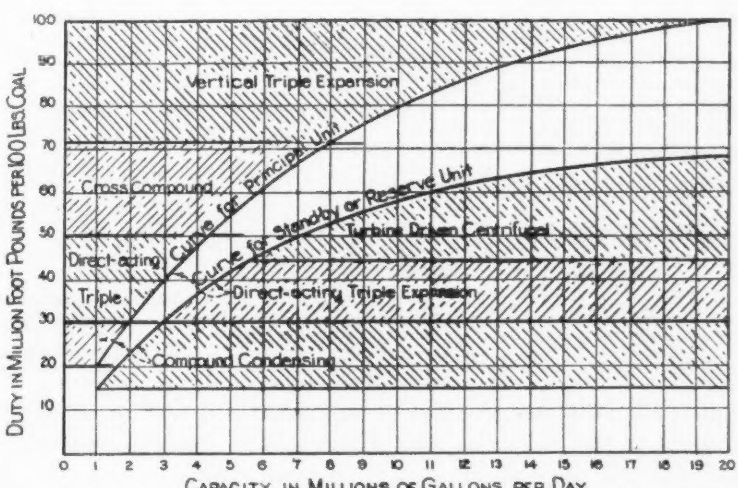


FIG. 3

Expectancy Curves
for
Pumping Engines
working against a
Pressure of 100 lbs.

false apprehensions and even though at first glance the results look attractive, the operator must not forget that the underwriters' requirements are yet to be reckoned with.

Figure 3, attempts to represent graphically the writer's ideas, under general conditions, of the machines that should be selected for certain capacities for both principal engine and alternate and the station duty they may be expected to produce, but you must realize that this intends the principal engine doing at least 90 per cent of the work and that the head, the cost of coal, the load factor, the cost of real estate in the construction of new plants or additions to old ones, and where the machine must be installed in existing stations, the boiler pressure and space available, and finally, in both cases, the funds available, are factors which may shift both the horizontal and the curved lines.

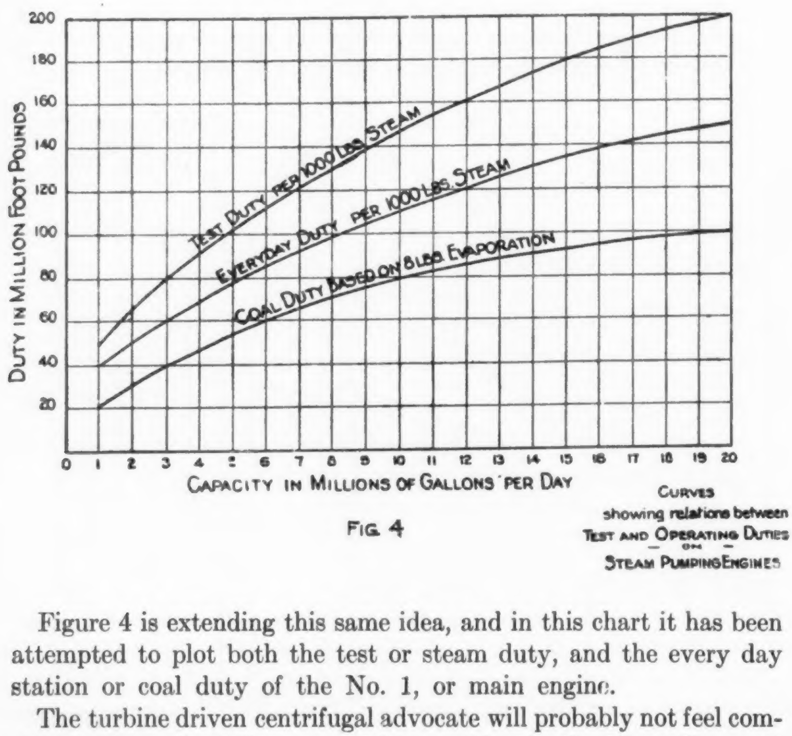


FIG. 4

Figure 4 is extending this same idea, and in this chart it has been attempted to plot both the test or steam duty, and the every day station or coal duty of the No. 1, or main engine.

The turbine driven centrifugal advocate will probably not feel complimented by the failure to get his machine in the No. 1 line, and this table must only be construed as portraying that under the

conditions assumed, it is not most applicable as No. 1 and not that conditions might arise where it would be more applicable than the reciprocating machine even as No. 1.

The steam turbine, as a power producer, has made in the past five years more rapid strides in economy than any other type of steam motor, and many of us will live to see it almost entirely supplant the reciprocating engine.

For the purpose of driving electric generators above 500 K.W. capacity, it holds the field alone, but as a driver of large pumps, there must necessarily intervene, for best results as to economy, gears which are objectionable both from the standpoint of their noise and their upkeep. In small units, the high vacuum necessary to produce the economy which steam turbine builders claim is difficult to produce and seldom forthcoming after the duty test is made.

In the field of filter or low service pumps of ten million capacity or over, the centrifugal pump reigns supreme, and for constant low heads of 20,000,000 capacity or over the turbine driven centrifugal usurps the field.

The curves above presented and the opinions they delineate are for the state of the art as of today. That there has been frequent shifting of these lines in the past five years argues that they will further shift in the future. During the period of low prices just past, the cross compound for a time almost wholly usurped the field of the direct acting triple, and with the rapid strides that the turbine driven centrifugal has made, as above predicted, its field will rapidly enlarge and the first machine that the writer expects it to crowd wholly from the map is the vertical triple expansion crank and fly wheel.

TESTS OF LOSS OF HEAD IN STRAINERS, ORIFICES AND SAND

By Langdon Pearse

The data given in this paper are derived from experiments made by Mr. W. W. DeBerard and the author in 1908, during filtration investigations for the Peoples Water Company of Oakland, California.

The tests of the loss of head in strainers used in rapid filters and in small orifices were made in an apparatus (fig. 1) consisting of a redwood box, 18 by 18 inches square and 12 inches deep, inside measurements, a set of 4 inch pipe and flanges arranged as shown, a three-quarter inch regulating valve, a level rod fitted with a hook gauge, a gauge glass, rubber connecting tube and a collecting bucket, holding about 45 pounds of water. Platform scales completed the equipment. The rig was set up in the testing station, the box being supported on wooden legs, while the pail was set on a sink with a drain to the sewer. At first the supply was taken from coagulated water, but the presence of floc, even though fine screen was used, quickly forced a change to clear water.

The method of operation was as follows: the orifice plate to be tested was set in position between the two flanges of the 2 inch flange union, with a rubber gasket on each side. The valve was then opened and the water allowed to flow through, the joint being carefully inspected for leaks. All the bolts in the flanges were thoroughly tightened before complete submergence. Water was then turned into the box, and when the water had risen above the flange union all the air underneath was sucked out with a small rubber tube. The space underneath was always tested for air after each run at a given head, but little air was found, after the first removal. The water was then allowed to rise in the standpipe to the desired head, and when the level in the box had attained a constant elevation, the hook gauge was set. At first the valve was set, the readings of the head being taken every ten seconds on the water column. It was found better to maintain a constant level, which was readily accom-

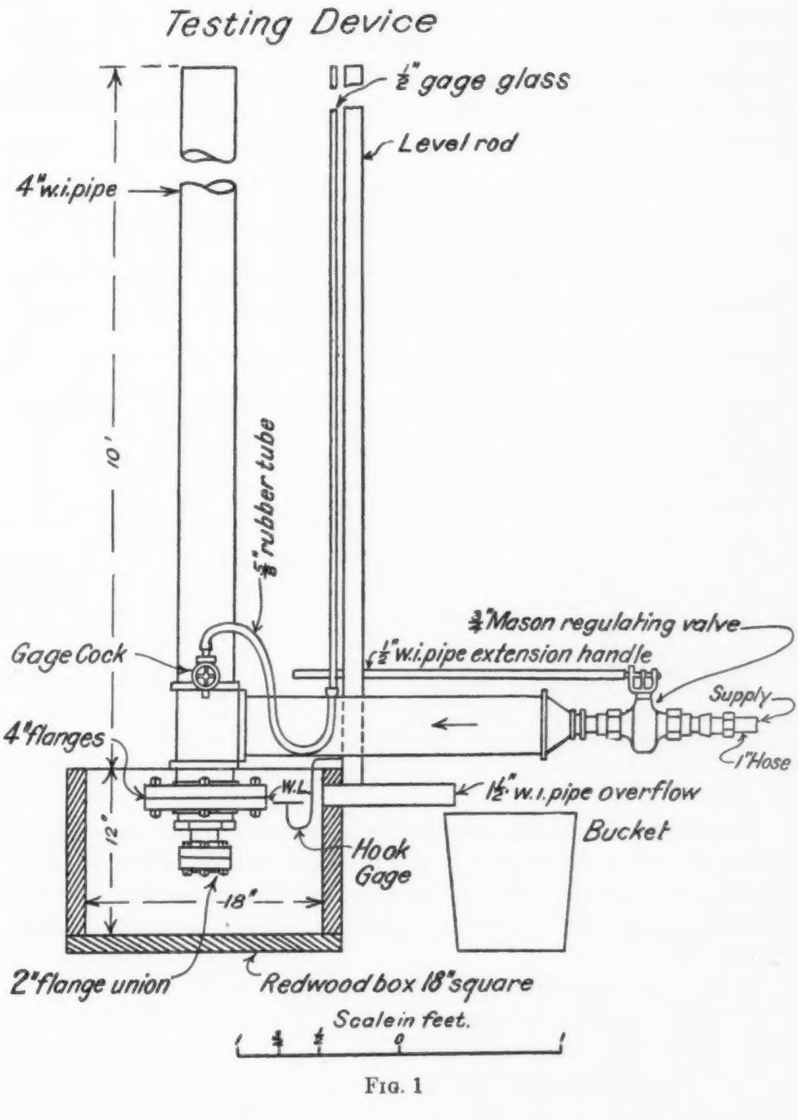

Testing Device
1/2" gage glass
Level rod
4" w.i. pipe
10'
5/8" rubber tube
3/4" Mason regulating valve
Gage Cock
1/2" w.i. pipe extension handle
Supply
4" flanges
1" Hose
W.L.
1 1/2" w.i. pipe overflow
Bucket
12"
Hook Gage
18"
2" flange union
Redwood box 18" square
Scale in feet.

FIG. 1

plished by the aid of the extension handle on the regulation valve. When the apparatus had been running smoothly for a few minutes, usually two and not over five, the bucket was swung under the overflow and allowed to fill for an even number of minutes. It was then removed, weighed on scales, and then emptied. The weight of a cubic foot of water was taken at 62.4 pounds. No correction was made for temperature.

TABLE 1

Tests of orifices

ORIFICE NUMBER	NOMINAL DIMENSION		ACTUAL DIMENSION		RATIO	AVERAGE VALUE C	RANGE OF HEAD FEET	NUMBER OF TESTS AVERAGED
	d	t	d	t	$\frac{d}{t}$			
	in.	*in.*	*in.*	*in.*				
54	$\frac{1}{4}$	$\frac{1}{16}$	0.2486	0.0601	4.138	0.624	1.25– 9.91	13
53	$\frac{3}{16}$	$\frac{1}{16}$	0.189	0.0601	3.15	0.612	2.0 –10.0	13
52	$\frac{5}{32}$	$\frac{1}{16}$	0.1569	0.0601	2.61	0.622	1.20–10.0	11
51	$\frac{1}{8}$	$\frac{1}{16}$	0.1266	0.0601	2.11	0.685	1.99–10.0	10
50	$\frac{3}{32}$	$\frac{1}{16}$	0.093	0.0601	1.547	0.68	1.20–10.0	10
49	$\frac{1}{16}$	$\frac{1}{16}$	0.0619	0.0601	1.03	0.741*†	1.99–10.0	9
48	$\frac{1}{4}$	$\frac{5}{64}$	0.25	0.0801	3.01	0.612	1.92– 9.8	11
47	$\frac{3}{16}$	$\frac{5}{64}$	0.1904	0.0801	2.38	0.612	1.99– 9.92	5
46	$\frac{5}{32}$	$\frac{5}{64}$	0.1572	0.0801	1.96	0.678	2.0 –10.0	5
45	$\frac{1}{8}$	$\frac{5}{64}$	0.1272	0.0801	1.59	0.718	2.0 –10.0	5
44	$\frac{3}{32}$	$\frac{5}{64}$	0.0935	0.0801	1.17	0.739	2.0 –10.0	5
43	$\frac{1}{16}$	$\frac{5}{64}$	0.0609	0.0801	0.761	0.852	2.0 –10.0	5

* Averaged from 2 sets, C = 0.689 and C = 0.794.

† Averaged from 2 sets, C = 0.780 and C = 0.640.

As all the tests were made with the orifices or strainers submerged, the head "h" in feet, given in the tables, is the actual head lost in passing through the orifice or strainer, and is measured by the difference of level of the water inside the standpipe and inside the redwood box.

In the tables the following abbreviations are used:

d = diameter of orifice

t = thickness of plate

C = coefficient of discharge

Table 1 shows a summary of the tests of orifices. These orifices were holes drilled through steel plates of the thickness noted, all burrs being carefully removed. The results indicate a coefficient of dis-

charge ranging from 0.62 where the ratio of $\frac{d}{t} = 4.1$ up to 0.85 with a ration of $\frac{d}{t} = 0.76$. With a very few exceptions the coefficient "C" varied but little for the range of head tried on any one orifice. On orifices 50 and 49, two independent sets of observations gave results somewhat at variance as noted.

TABLE 2

Test of Wilson strainer. Used at Binghamton, New York

Total area slots = 1.101 square inches = 0.00764 square foot. $Q = 0.0613\, C \sqrt{h}$.

Area w.i. pipe = 0.864 square inch = 0.006 square foot. $Q = 0.0481\, C \sqrt{h}$.

POUNDS PER MINUTE	CUBIC FEET PER SECOND	HEAD IN FEET	$\sqrt{h}$	VALUE OF C	
				Area Slots	Area Pipe
112.6	0.0301	2.173	1.474	0.333	0.425
150.2	0.0401	3.96	1.99	0.329	0.419
200.5	0.0536	7.18	2.68	0.326	0.416
Average				0.329	0.420

TABLE 3

Test of Denver strainer. Used by Denver Union Water Company, Denver, Colorado

Copper plate $2\frac{5}{8}$ inches diameter. 0.023 inch thick contains 1098 effective holes each 0.032 inch diameter.

Total area holes = 1098 (0.000805) = 8.885 square inches = 0.00614 square foot.

Ratio $\frac{d}{t} = \frac{0.032}{0.023} = 1.39$. $Q = 0.0492\, C \sqrt{h}$.

GALLONS PER MINUTE	CUBIC FEET PER SECOND	HEAD IN FEET	$\sqrt{h}$	VALUE OF C		REMARKS
				As obtained	Corrected	
17.5	0.0373	1.10	1.049	0.723	0.723	
22.1	0.0471	1.76	1.326	0.722	0.735	20 holes plugged
26.1	0.0557	2.42	1.555	0.728	0.736	18 holes plugged
Average				0.724	0.731	

TABLE 4

Test of Greer strainer

Total area slots, 0.4844 square inch = 0.003363 square foot. $Q = C \times 0.0269 \sqrt{h}$.

Area throat, 0.132 square inch = 0.000917 square foot. $Q = C \times 0.007354 \sqrt{h}$.

POUNDS PER MINUTE	Q CUBIC FEET PER SECOND	h	$\sqrt{h}$	VALUE OF C		REMARKS
				Throat	Slots	
19.05	0.00509	1.074	1.036	0.6685	0.182	2 runs
28.02	0.00749	2.067	1.438	0.708	0.193	3 runs
40.00	0.01069	4.08	2.02	0.719	0.196	2 runs
48.88	0.01306	6.11	2.47	0.718	0.196	4 runs
55.22	0.01476	7.654	2.769	0.725	0.1977	4 runs
Average				0.7077	0.1929	

TABLE 5

Test of Little Falls strainer. Used at Little Falls, New York

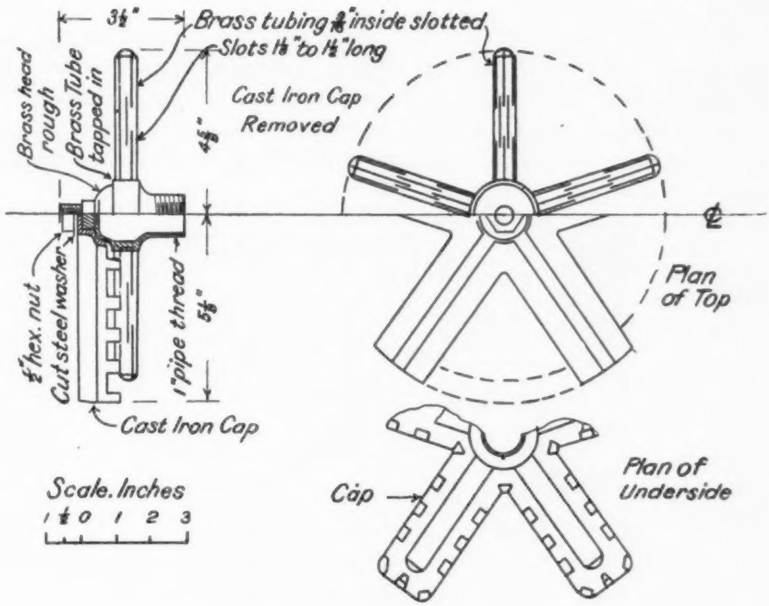
Total area of holes, 0.1161 square inch = 0.000806 square foot. $Q = C \times 0.006464 \sqrt{h}$.

Area inlet pipe, 0.1135 square inch = 0.000788 square foot. $Q = C \times 0.00632 \sqrt{h}$.

POUNDS PER MINUTE	Q CUBIC FEET PER SECOND	H HEAD IN FEET	$\sqrt{h}$	VALUE OF C		REMARKS
				Inlet	Holes	
12.05	0.00324	1.143	1.07	0.480	0.469	3 runs
16.00	0.00427	1.97	1.404	0.481	0.471	3 runs
23.42	0.00626	4.12	2.03	0.488	0.477	3 runs
23.09	0.0075	5.95	2.44	0.487	0.476	3 runs
32.60	0.00869	8.03	2.832	0.486	0.475	3 runs
36.38	0.00972	9.87	3.14	0.49	0.479	3 runs
Average				0.485	0.4745	

Tables 2, 3, 4 and 5 give the data obtained on the strainers of the Wilson, Denver, Greer and Little Falls types. The dimensions of the strainers tested are given in figures 2, 3, 4 and 5. The resulting C is computed on both the supply pipe and the openings for strainers of the Wilson, Greer and Little Falls type.

The Columbus, Ohio, strainer plate is shown on figure 6. The average coefficient C was 0.736 for heads varying from 1 to 10 feet. This is an average of 28 observations.



Data on Slots

Length per pipe in.	Width in.	Area sq. in.
25 3/16	0.009	0.23
24	0.009	0.216
16 1/16	0.009	0.146
6	0.013	0.078
23 1/4	0.009	0.209
24 5/8	0.009	0.222

Weight of Materials
Cast Iron Cap, Nut, Washer 4 lb. 6 oz.
Brass Head and Tubes 1 lb.

FIG. 2. WILSON STRAINER

The tests of loss of head in the strainers and sand were made in the working experimental filters each 4 feet square inside dimensions.

In filter 2, the underdrain was of the combined type designed to use air and water alternately through a single pipe system similar to the one installed at Harrisburg, Pennsylvania. This underdrain consisted of a 3 inch galvanized-iron pipe header with eight lateral pipes, $1\frac{1}{4}$ inches diameter, spaced 6 inches center to center. On the under

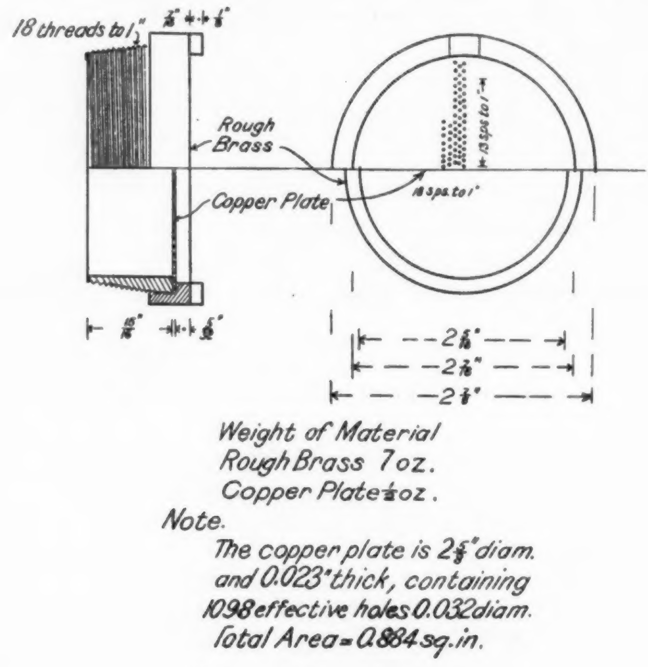


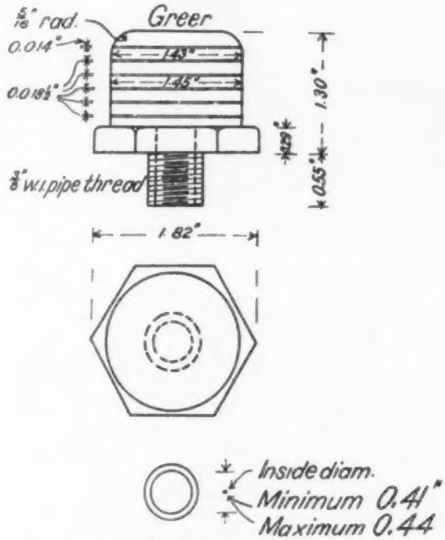
FIG. 3. DENVER STRAINER

side of the pipes are drilled $\frac{7}{32}$ inch diameter holes, 3 inches center to center making eight rows of 16 holes each, a total of 128 holes, with a total area of 4.81 square inches equivalent to about 0.21 of 1 per cent of the area of the filter.

Filter 3 was designed for a high-rate wash, with water only, using a pipe system similar to the first, but with a 4 inch header and 2 inch laterals. On the under side of the pipes there are drilled eight rows of 15 holes each, approximately $\frac{5}{16}$ inch diameter. The total area

of the holes is 9.204 square inches, equivalent to 0.40 of one per cent of the area of the filter. A wire screen was placed over the gravel and tied down to prevent displacement by the high velocity of the wash water.

Filter 4 has an underdrain modeled after that at Cincinnati, Ohio, except that it is built of wood instead of concrete, and the wire



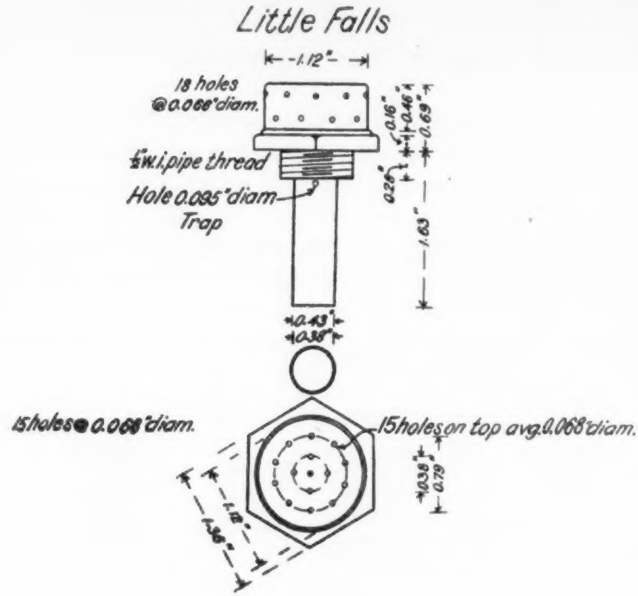
Data

Description	Diam in.	Area Sq. in.
Slots		0.4844
Inlet	0.41	0.132

Material Brass
Weight 5 oz.

FIG. 4 GREER STRAINER

screens over the gravel are omitted. There are six plates, each containing 58 holes $\frac{3}{16}$ inches in diameter. The total area of the 348 holes in the plates is 9.6 square inches, equivalent to 0.42 of 1 per cent of the area of the filter. During the experiments the filter was rebuilt, using plates each containing the same number of holes as before, but $\frac{1}{8}$ inch in diameter, equivalent to 0.19 of 1 per cent of the area of the filter.

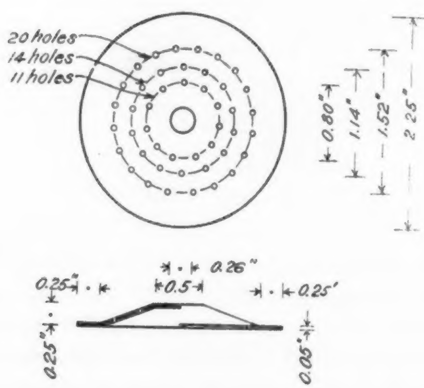


Data

Description	Diam. in.	Area Sq. in.
Inlet Pipe	0.38	0.1135
Trap Hole	0.095	0.0071
Holes 33		0.1161

Material Brass
Weight 2 oz.

Fig. 5



Holes 45 Avg. diam. 0.065 in.
Total Area 0.1493 sq. in.
Weight brass plate, yoke and bolt 2 ½ oz.

Fig. 6 Columbus Strainer

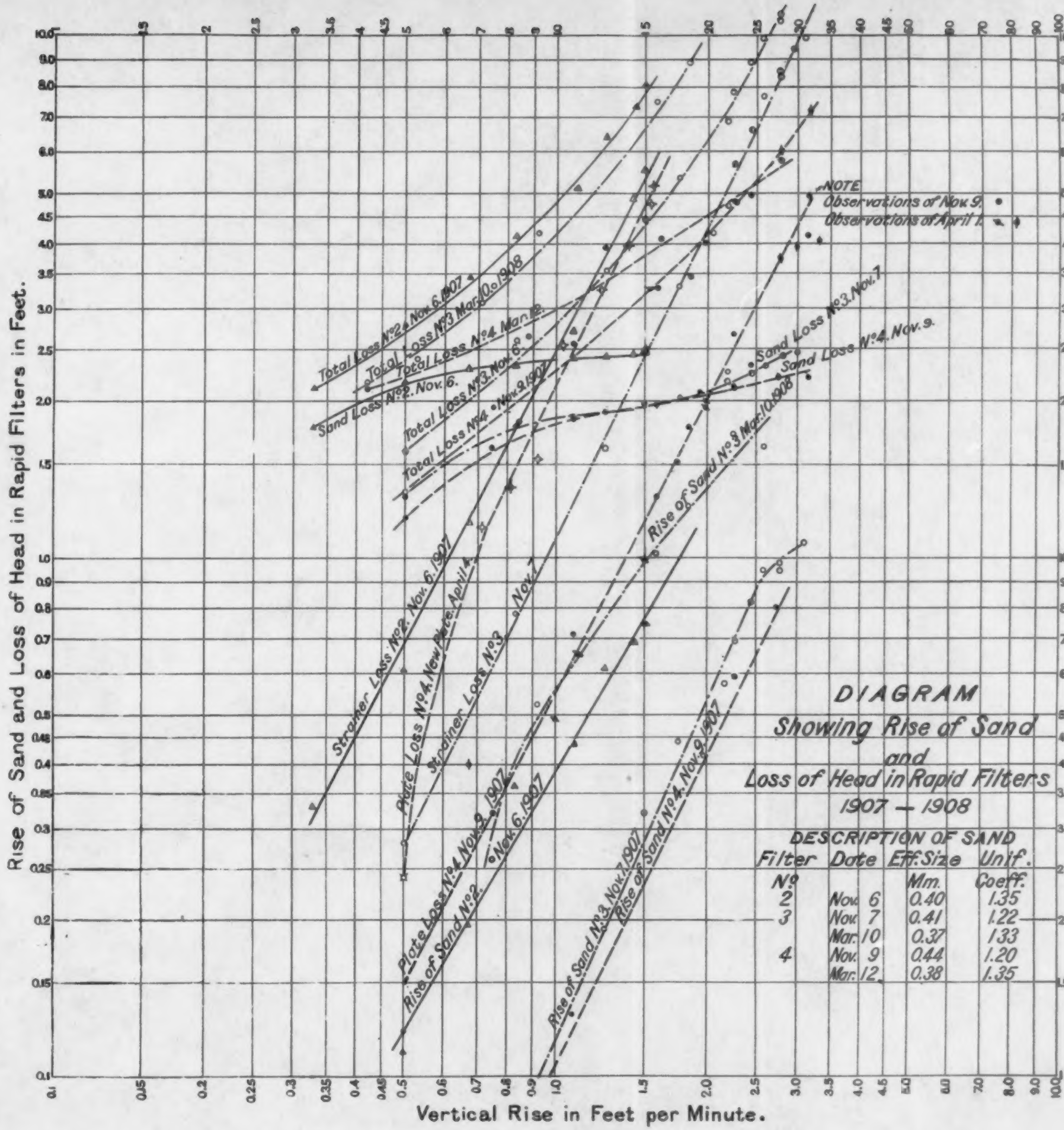


FIG. 7. RISE OF SAND AND LOSS OF HEAD FOR VARIOUS RATES OF VERTICAL RISE OF WASH WATER

The curves plotted in figure 7 are on a logarithmic scale. In each case for filters 2, 3 and 4 a curve is drawn showing the strainer or plate loss, the sand loss, and the total loss of head through both strainer and sand for various rates of wash water. In addition the rise of the sand is given. The analysis of the sand is noted on the diagram. In general the finer sand with a higher uniformity coefficient rose to a greater height with a given vertical rise of wash water.

The data given in this paper are not always of the highest degree of accuracy, owing to the conditions under which the experiments were made. They are, however, of value as an aid to judgment in selecting coefficients or in studying the behavior of sand filters. Further data acquired along these lines in actual plants would be of service.

CITY TUNNEL OF THE CATSKILL AQUEDUCT[1]

By Walter E. Spear[2]

The peculiar topography of Manhattan Island, the relatively few streets in the older portions of New York City not already occupied by subways, pipes and ducts, and the swift tidal waters which separate the several boroughs of the city combined to make the problem of delivering the Catskill supply under full pressure to the great centers of population one of some difficulty. Until the problem was thoroughly investigated, the only way to provide for the distribution of the Catskill water appeared to be that of supplementing the existing conduits of the Croton system in the boroughs of The Bronx and Manhattan and constructing new pipe lines through the less congested streets in the borough of The Bronx from Hill View just north of the city line, to the borough of Queens, and thence to the boroughs of Brooklyn and Richmond. Except by laying a large number of independent trunk mains of large capacity to the lower end of Manhattan Island, a task physically almost impossible in the crowded streets, downtown New York could not secure the full advantages of increased pressure for fire protection and domestic consumption that the new system provides. Even if it had been possible to lay in the streets a large number of new pipe lines, the cost of such a system would have been about twice as much as the cost of the single conduit of the same capacity of more permanent construction that was finally adopted. Some type of pressure conduit of ample dimensions was required, because, even in The Bronx and upper Manhattan where the streets were comparatively free of subsurface structures, the ground was not at a sufficiently high elevation to permit the construction near the surface of a large masonry conduit like the Old Croton Aqueduct, because the Catskill supply when it reaches the city line is at an elevation of 295 feet above sea level or about 150 feet higher than the Croton supply.

[1] A paper read at the March, 1916, Meeting of the New York Section, illustrated by lantern slides.

[2] Department Engineer, Board of Water Supply.

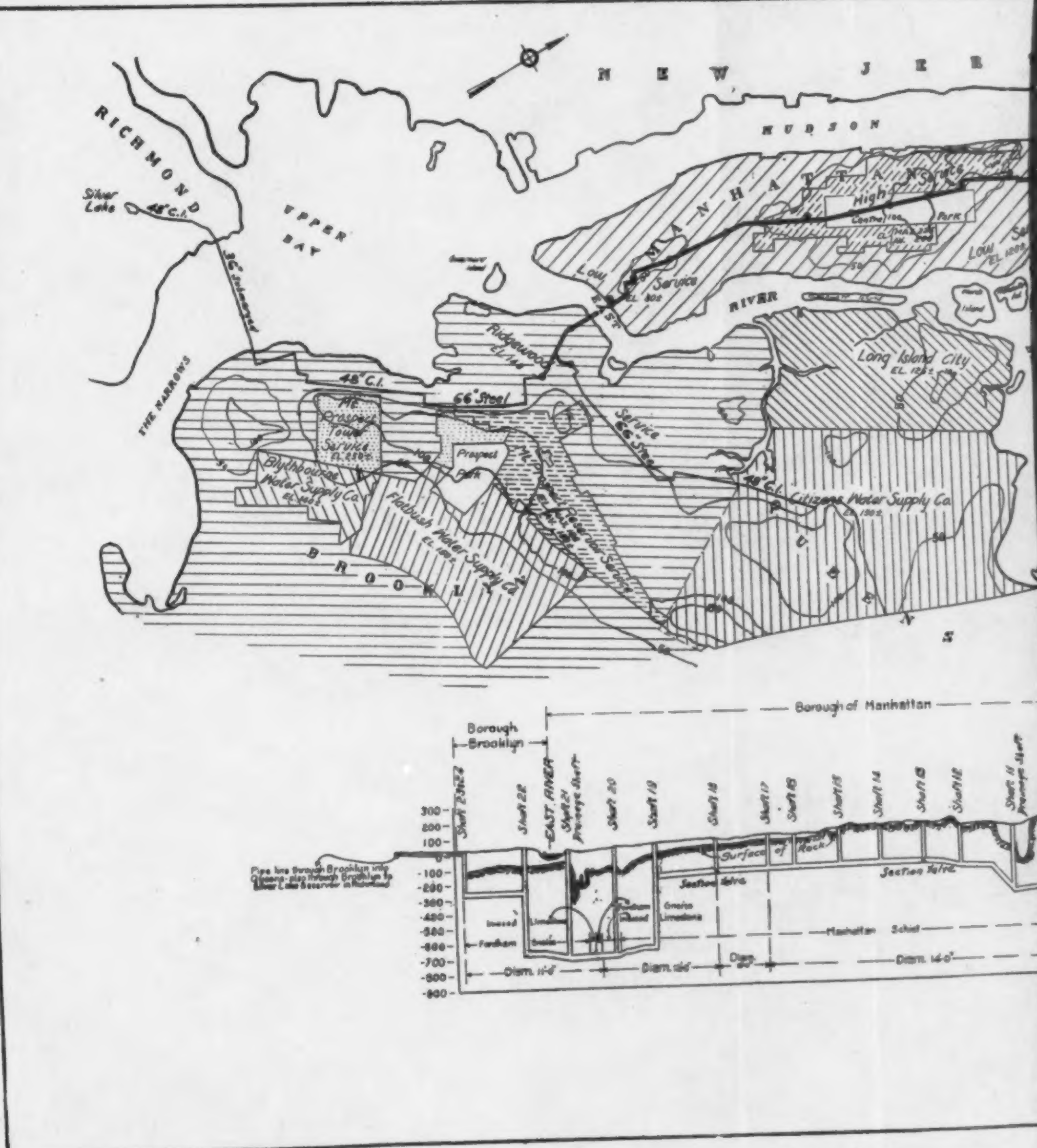
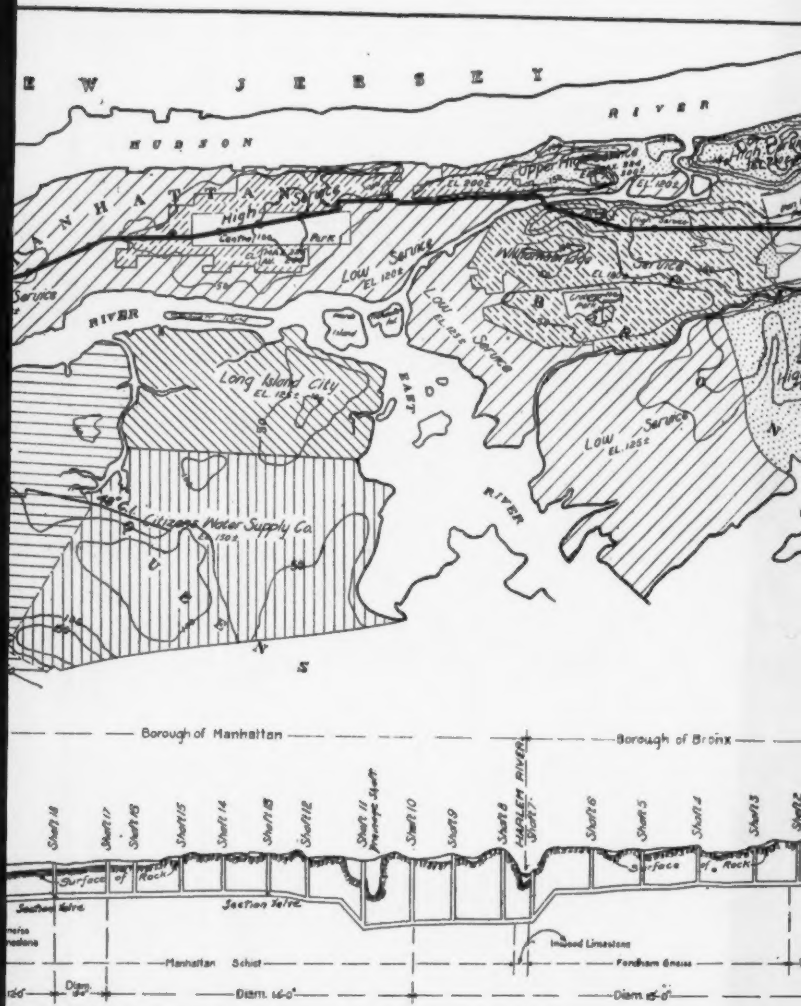

NEW JER
HUDSON
RICHMOND
Silver Lake
48" C.I.
UPPER BAY
36" Submerged
THE NARROWS
MANHATTAN
High Service
Central Park
Low Service
EL. 80
EAST RIVER
Ridgewood
EL. 146
Long Island City
48" C.I.
66" Steel
Mt. Prospect Tower Service
EL. 258
Prospect Park
Blythbourne Water Supply Co.
Flatbush Water Supply Co.
Service
66" Steel
48" C.I.
Citizens Water Supply Co.
BROOKLYN
QUEENS
Borough of Manhattan
Borough Brooklyn
Shaft 22
EAST RIVER
Shaft 21
Shaft 20
Shaft 19
Shaft 18
Shaft 17
Shaft 16
Shaft 15
Shaft 14
Shaft 13
Shaft 12
Shaft 11
Surface of Rock
Section Valve
Manhattan Schist
Fordham
Inwood
Limestone
Gneiss
Diam. 11'-0"
Diam. 14'-0"
300
200
100
0
-100
-200
-300
-400
-500
-600
-700
-800
-900

PLATE I



PLAN AND PROFILE OF CITY

PLATE I

OF CITY TUNNEL

While bed rock, which outcrops so frequently in The Bronx and upper Manhattan, would have offered much difficulty to the construction of a surface aqueduct or pipe line, it furnished a unique solution of the distribution problem, since it permitted the construction of a deep pressure tunnel in rock of the full capacity of the Catskill sources, from Hill View reservoir, through the boroughs of The Bronx and Manhattan to the downtown business district of Brooklyn, the tunnel serving as a great trunk distribution main, delivering water through frequent outlets at high pressure to the dense areas of population in these older parts of the city and also supplying, through pipe lines, the outlying districts in the boroughs of Brooklyn, Queens and Richmond.

As a result of surveys, borings and extended studies, covering a period of about two years, the location shown on Plate I, for the deep rock pressure tunnel, which is known as the City tunnel, was finally chosen. This location, which for its entire length is under streets and parks, follows in a general way the higher ground in the westerly portion of The Bronx and upper Manhattan, passes through Central Park, Sixth Avenue, Broadway and Fourth Avenue to the lower east side and thence across the East River to Brooklyn, where the rock floor becomes too low to carry this type of construction further. The city tunnel was driven at a depth of not less than 150 feet below the surface of sound rock, as determined by the outcrops and borings, in order to insure good driving, a minimum of water during construction and a tight waterway in service. This requirement placed the tunnel for over half its length in the Yonkers and Fordham gneiss formations of The Bronx and in the schist of Manhattan at a depth below the surface of about 200 feet. As indicated on the profile in Plate I, a somewhat greater depth, about 300 feet below sea level, was necessary from the Harlem River to the head of Central Park in order to secure sufficient cover in the Inwood limestone, beneath the Harlem River, and in the Manhattan schist at 123d Street. A still deeper depression, 700 feet below sea level, had to be made beneath the lower east side because of the great depth of decay there in the rock of the Fordham gneiss and Inwood limestone formations.

The city tunnel is 18 miles in length from Hill View reservoir to the terminal shafts in Brooklyn, and its finished diameter is 15 feet for the first 8 miles reducing from this size by successive decrements of 12 inches to 11 feet in Brooklyn. Of the 24 shafts

through which the tunnel was constructed, 22 were built as waterway shafts through which the Catskill supply could be delivered to the street mains. Shaft 1, a construction shaft, was plugged and Shaft 11 has no waterway. Two shafts, 11 and 21, both located at low points in the tunnel profile, were built as drainage shafts through which to unwater the tunnel for inspection and repairs. Beyond the terminal shafts in Brooklyn, trunk mains of 66-inch steel and 48-inch cast iron were laid through the streets to the boroughs of Queens and Richmond. In crossing the Narrows to Staten Island, two 36-inch flexible jointed cast-iron pipes were planned, one of which is now being laid.

One of the many unusual features of the city tunnel is the arrangement for cutting the tunnel into three sections by means of two section valves set in the main tunnel at the foot of Shafts 13 and 18. These section valves are of bronze, 66 inches in diameter, and each is operated by a hydraulic cylinder in the chamber at the top of the shaft.

SHAFT SINKING

With the exception of the six southerly shafts, Nos. 19 to 24 inclusive, the shafts in earth were excavated by ordinary open-cut methods. The excavations of the earth portions of shaft 19 to 24 presented unusual difficulties, on account of the greater depth to rock, and the proximity of elevated railways, subways and other subsurface structures. These shafts were sunk to rock by means of reinforced concrete caissons under compressed air. Except at Shaft 21, where 4 rectangular caissons were sunk to provide foundations for the superstructure, the caissons were from 18 to 24 feet in diameter with walls from 2 to 3 feet thick. The bottoms of the caissons were carried from 2 to 5 feet below the surface of sound rock in order to provide for a tight seal and permit the rock shafts to be excavated in free air without any inflow of water. A view of the caisson at Shaft 23 is shown on Plate II. At this shaft the rock is 140 feet below the surface and 95 feet of this depth is in water bearing sand. At the time this view was taken, about 40 feet of the caisson was below and 80 feet above the surface of the ground. An air pressure of 46 pounds per square inch was maintained for two weeks at this shaft during the excavation of the rock and the sealing of the caisson. From two to three months were consumed at Shafts 19 to 24 in sinking each of the caissons before excavation of the rock shaft could be begun.

PLATE II

With the exception of Shafts 13 to 18, which were approximately rectangular in shape and were timbered as they were excavated, the shafts in rock were circular in shape, and were lined with concrete in stretches of about 100 feet as the excavation progressed. A finished diameter of 14 feet within this concrete lining was provided in all but three shafts which had diameters of 16 to 18 feet. From 25 to 30 feet of rock shaft were frequently excavated per week, but the average progress was less, on account of interruptions in sinking due to placing of concrete lining and because of delays occasioned by inflowing water. The average monthly progress for all shafts was 47 feet, and from 3 to 14 months were consumed at each shaft in sinking the shafts and placing the concrete lining.

All water encountered in the rock seams of the shafts was grouted off as far as possible in advance of the excavation, since it is difficult to find room for pumps to handle any considerable inflow without seriously interfering with the operations of drilling and mucking. At Shaft 4, near Jerome Park reservoir, a wide zone of broken and decayed rock was found near the bottom of the shaft which yielded a flow of 120 gallons per minute under a pressure of 70 pounds per square inch. The same crushed zone was later penetrated in the tunnel, where a flow of 400 gallons per minute was found. In sinking the shaft through this ground, many holes were drilled in the bottom, around the periphery of the shaft, to reach the water bearing seams, and grouting was carried on through these holes for several weeks. This grouting was partially successful in cutting off the flow, but it was not until the concrete lining had been placed and the shaft grouted, that the water was entirely cut off.

EXCAVATION OF TUNNEL

The preliminary borings indicated that no serious difficulties would be met in driving the tunnel. Some heavy ground requiring permanent steel roof support was encountered in several sections and in three stretches, one in the gneiss near Jerome Park reservoir, one in the limestone under Harlem River, and another in the granodiorite in Brooklyn, considerable water was met in the tunnel headings, but in no case was the flow so large as to greatly interfere with the excavation. The greatest flow, that in Brooklyn, was only 600 gallons per minute, and as soon as adequate pump-

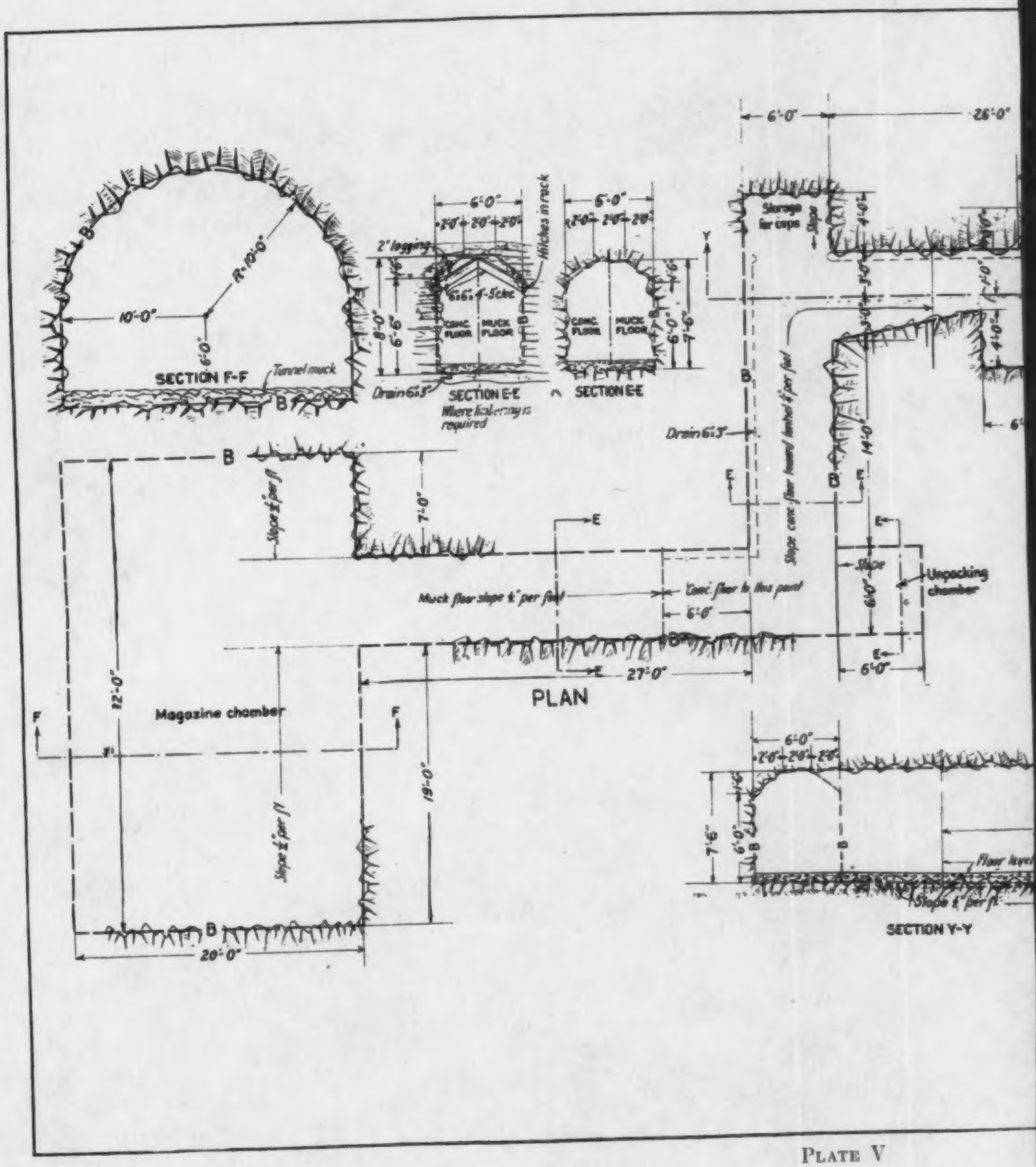

SECTION F-F
Tunnel muck
R-10'-0"
10'-0"
6'-0"
SECTION E-E
Where lagging is required
SECTION E-E
2" lagging
Hitches in rock
CONC. FLOOR
MUCK FLOOR
Drain 6x3"
Storage for caps
PLAN
Magazine chamber
Muck floor slope ¼" per foot
Conc. floor to this point
Unpacking chamber
27'-0"
20'-0"
32'-0"
19'-0"
SECTION Y-Y
Floor level
Slope ¼" per ft

PLATE V

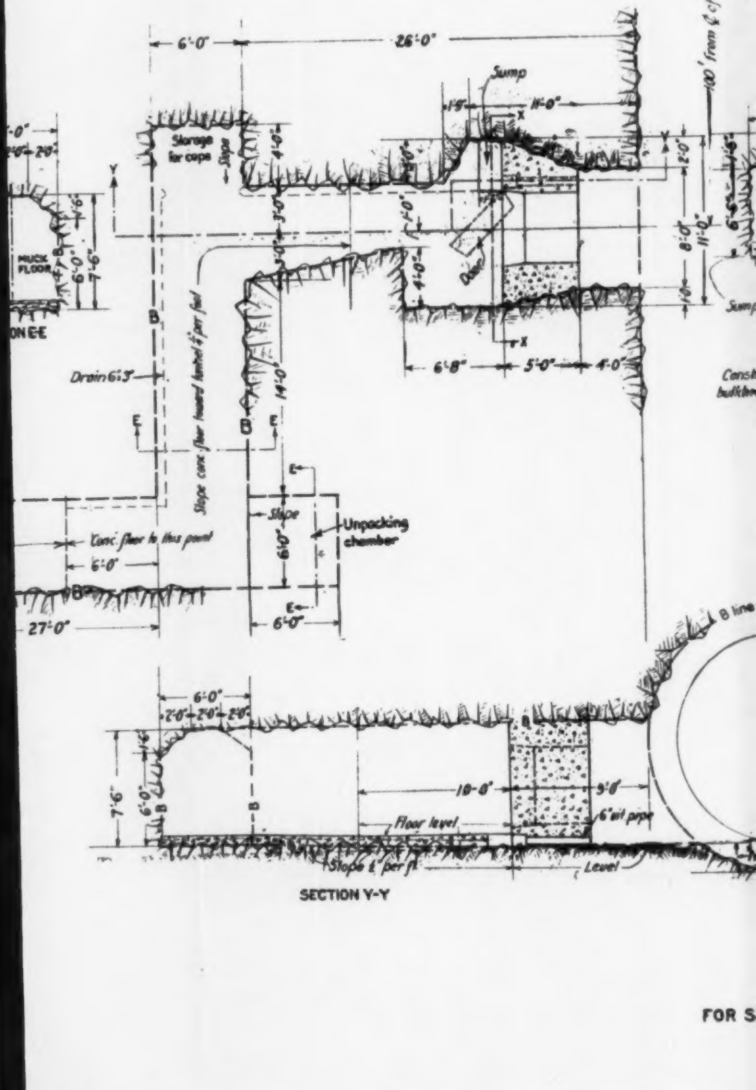
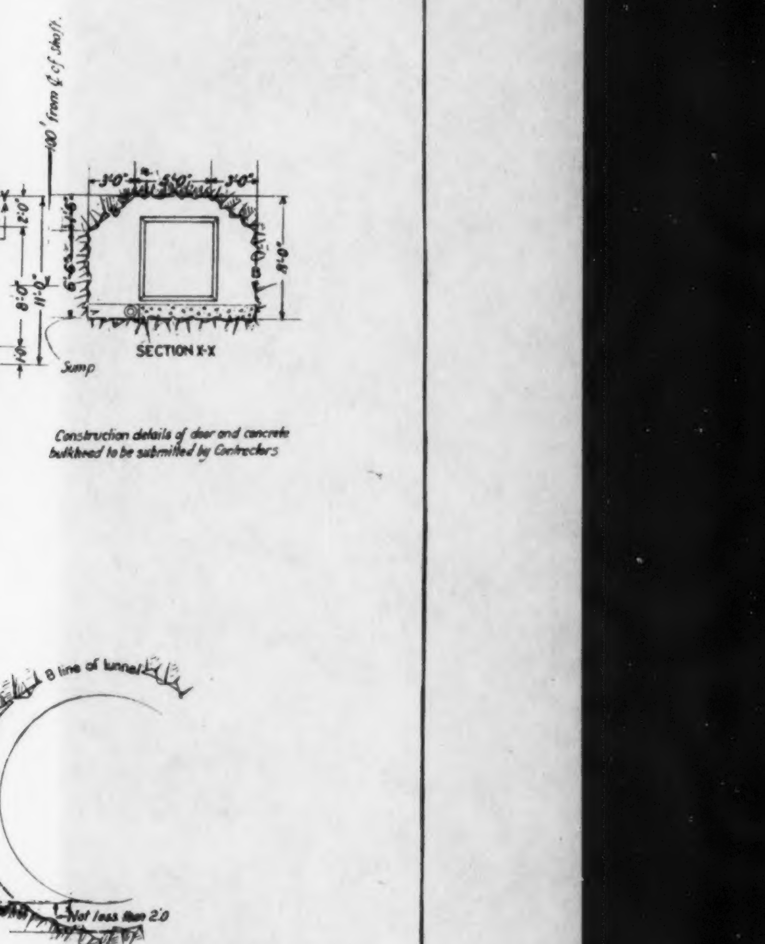

Sump
Storage for caps
Slope
Drain 6"3"
Slope conc. floor toward bulkhead ¼" per foot
Unpacking chamber
Conc. floor to this point
MUCK FLOOR
Floor level
6" oil pipe
Slope ⅛" per ft
Level
SECTION Y-Y
8 line
FOR S

PLATE V



UNDERGROUND MAGAZINE
FOR STORAGE OF 1000LBS. OF DYNAMITE

capacity was provided, the excavation was advanced with little delay. In this stretch grouting of the water bearing seams in advance of the driving was attempted, but without success, and the water was only cut off, as elsewhere, after the concrete lining of the tunnel had been placed and grouted.

The excavation of the tunnel, from the standpoint of cost and length of time required, was the largest item of the work, and the driving was prosecuted with the maximum of speed consistent with economy. The conditions in the city imposed on the contractors certain restrictions not generally encountered in work of this character. To avoid the noise and dirt incident to the use of steam, the contracts provided that as far as practicable electric power be used for all purposes. The regulations of the local authorities with regard to time of blasting required careful planning of the work until, as the headings were driven some distance from the shaft, more freedom in this respect was permitted.

Except for a short stretch excavated by the bottom heading method, the top heading and bench method, common in this country, was used in driving the tunnel. This method is shown on Plate IV. For the first year of the work 60 per cent Forcite was used, but for most of the rock excavation in the tunnel, the low freezing gelatine of the same strength was employed. This required no thawing and was therefore safer and more satisfactory. From 10 to 18 months were required to complete the tunnel excavation at each shaft. The best monthly progress made was 371 feet in one heading, and 652 feet in two headings, both in limestone, at Shaft 20. The average progress in one heading for the entire tunnel was 175 feet per month.

One of the important problems in connection with the driving of the tunnel was that of storing the large quantity of explosives necessary to carry on the work at the rate required under the contracts. The storage of 1000 pounds of dynamite at the top of each shaft in the built up portions of the city presented a serious problem to those responsible for the conduct of the work. After some study and investigation the underground magazine shown on Plate V was adopted. The magazine chamber in which the explosives were to be stored was excavated at the end of a tortuous drift, driven laterally from the main tunnel at a point distant about 100 feet from the foot of the shaft. A heavy door of steel beams and

timber was hung in such a position as to quickly close in the event of an accidental explosion in the magazine.

A cross section of the standard 15 foot tunnel in unsupported ground is shown on Plate III, this section being typical of the other sizes. The quantity of excavation and concrete for this type of tunnel is given below, the quantities being computed to the "B

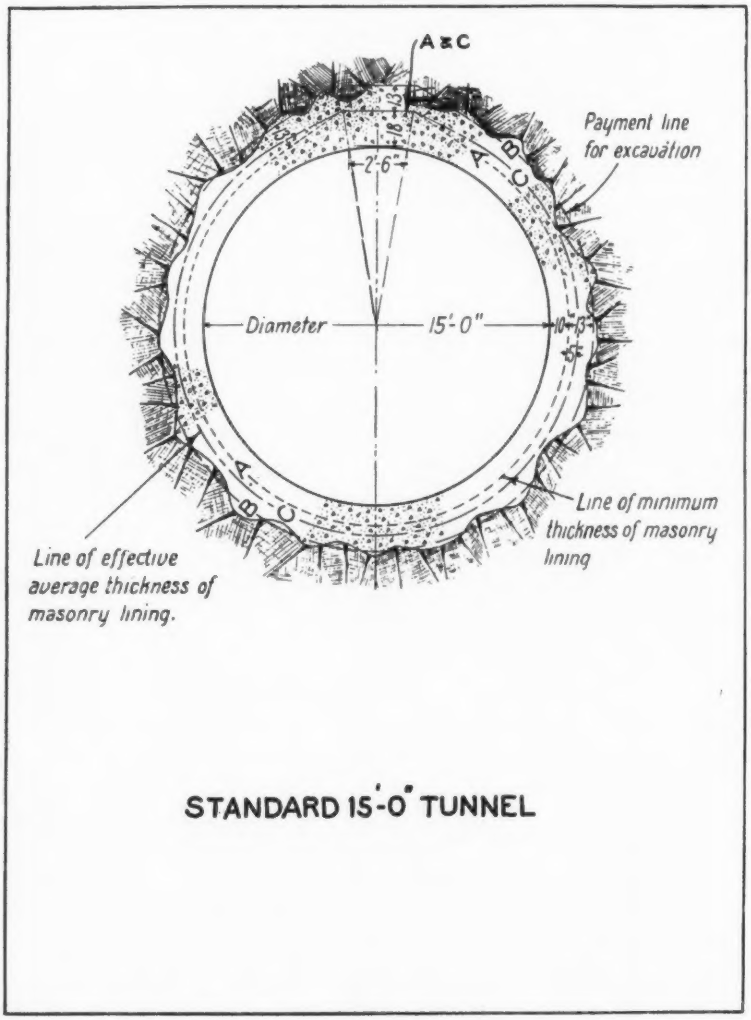
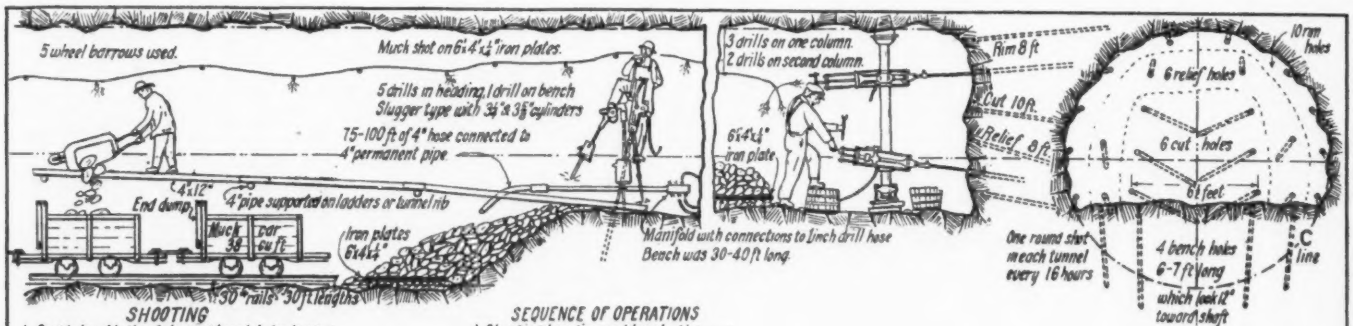


PLATE III



SHOOTING

1. 6 cut holes, 4 bottom holes and bench holes loaded.
2. Then 6 cut holes shot, rock falling clear of heading in large chunks.
3. Then 6 relief holes, remaining, loaded or all remaining holes loaded.
4. 8 relief holes shot, rock falling down and a part backward.
5. 10 rim holes shot, rock falling down, very little backward.
Bench usually shot with cut round of heading.

SEQUENCE OF OPERATIONS

1. Shooting heading and bench - 1½ hours
2. Delay on account of smoke - ½ hour
3. Clearing out heading - 4 hours.
4. Setting up columns and drills - 2 hours
5. Drilling and mucking - 8 hours

SKETCH SHOWING TYPICAL METHOD
OF EXCAVATION IN TUNNEL

PLATE IV

line" or payment line, corresponding to a distance of 10 inches to the "A line" which line defines the minimum thickness of concrete lining.

FINISHED DIAMETER OF TUNNEL	QUANTITIES PER LINEAR FOOT OF TUNNEL	
	Excavation	Concrete
feet	*cubic yards*	*cubic yards*
15	10.4912	3.9462
14	9.4268	3.7254
13	8.4212	3.5051
12	7.4016	3.2128
11	6.5109	2.9912

Under the provisions of the specifications, no point of rock was allowed to project within the "A" line shown on Plate III and no considerable area was permitted within the "C" line. On account of the alignment, the tunnel was driven very nearly parallel with the strike of the rock and some of the ground broke irregularly and wide, so that the actual excavation was on the average in all stretches of the tunnel in excess of the "B line," to which payment was made for both excavation and concrete, and thus giving an average thickness of concrete lining a little more than 23 inches.

In the 93,888 feet of tunnel within the city limits 6654 feet or 7.1 per cent was permanently supported with steel bents which were concreted into the lining. The amount of water encountered in the tunnel when first excavated aggregated 2436 gallons per minute but this amount gradually diminished as headings were advanced, and when the tunnel was finally lined and grouted, the total inward leakage was reduced to 130 gallons per minute.

TUNNEL LINING

The concrete lining was placed in three operations. The first step was to lay the invert in the bottom with radial joints and a top width varying from 4 to 6½ feet, the concrete being placed against wooden side forms. This work was carried on as a continuous operation and from 600 to 1500 feet were laid each week from one plant. After the invert was completed for a given stretch, the concrete in the sidewalls was placed, and then the arch. For this purpose collapsible steel forms of the Blaw type mounted on carriages running on

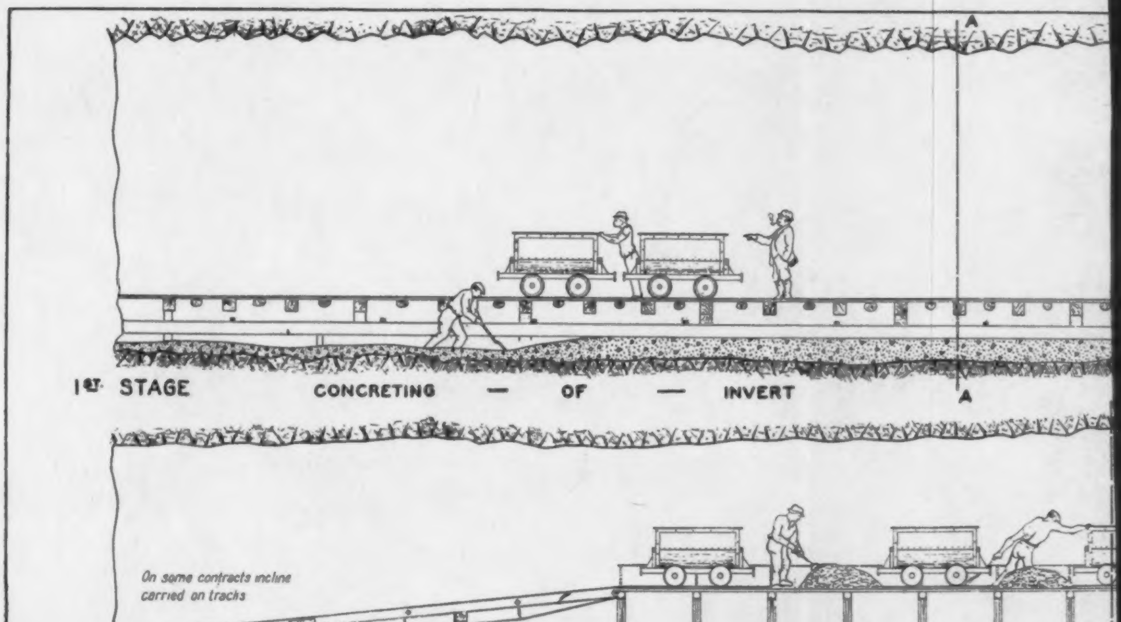
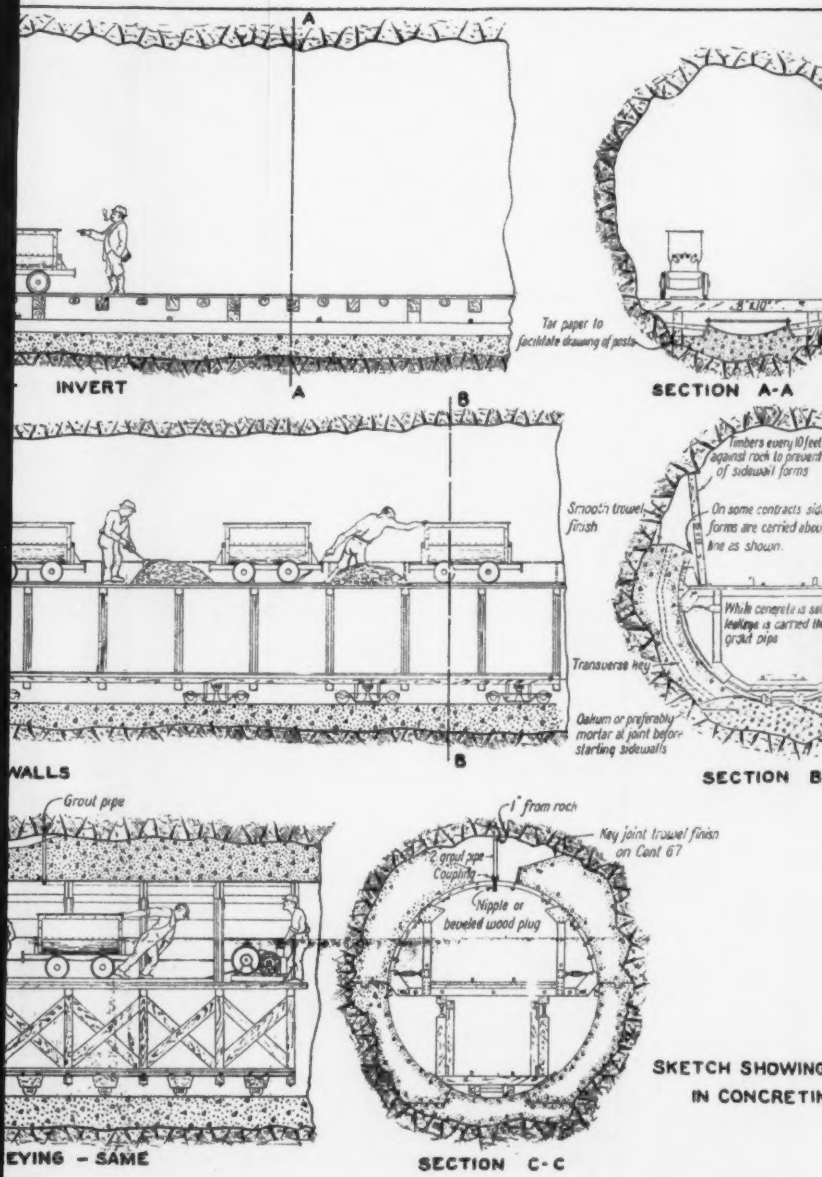

1st STAGE CONCRETING — OF — INVERT
On some contracts incline carried on tracks
2nd STAGE CONCRETING — OF — SIDEWALLS
Grout pipe
Arch forms
Sidewall forms
3rd STAGE CONCRETING - OF - ARCH - AND - KEYING - SAME

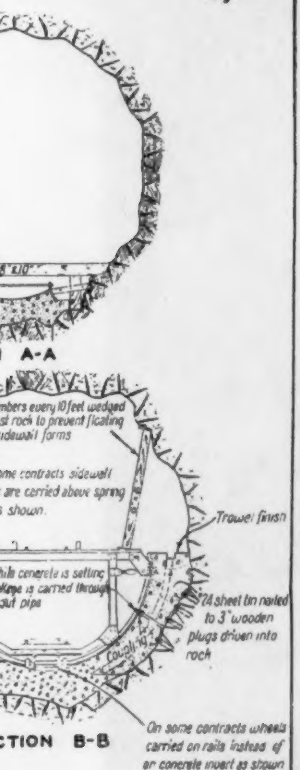
PLATE VI



A
INVERT
A
Tar paper to
facilitate drawing of posts
SECTION A-A
B
Smooth trowel
finish
Transverse key
Oakum or preferably
mortar at joint before
starting sidewalls
WALLS
B
SECTION B
Grout pipe
1" from rock
Key joint trowel finish
on Cont 67
2 grout pipe
Coupling
Nipple or
beveled wood plug
EYING - SAME
SECTION C-C
SKETCH SHOWING
IN CONCRETIN

PLATE VI

Fig. 16



SHOWING SUCCESSIVE STEPS
ONCRETING TUNNEL

the completed invert were used. For concreting the sidewall and arch, the forms were "trailed," that is, a length of sidewall form and an equal length of arch form were set up usually from 1 to 5 feet apart, the arch form trailing behind the sidewall form, as shown on Plate VI. The cars containing the concrete, in trains of 4 or 5 cars, were delivered to the foot of the incline, hauled up this incline by means of an electric hoist to the working platform set on the forms at approximately the level of the springing line and dumped, after which the concrete was shoveled by hand behind the forms.

The forms were usually from 60 to 100 feet in length; on one section, however, a set of sidewall and arch forms, each 150 feet long, was used. The shorter arch forms were keyed working continuously from one end, while with the longer forms, keying was started from two or three points and closures were made by means of a wooden box. Except for a somewhat drier mixture in the key of the arch, a wet plastic mix of $1:1\frac{1}{2}:3$ concrete was used throughout for the lining of the city tunnel. Some cracking developed in the sidewalls and arch between the joints defining the end of the day's work, but in very few instances did these cracks show any perceptible leakage.

In order to secure a dense, tight lining, provision was made to protect the concrete from inflowing water, while the concrete was being placed, by setting drip pans of galvanized iron or sheet steel, the pans being secured by nailing them to wooden plugs set in holes drilled in the rock. The water collected in these pans and escaped freely into the tunnel through weepers of $1\frac{1}{2}$-inch or 2-inch steel pipes, embedded in the concrete and extended through holes cut in the steel forms. The spaces between the pans and rock were subsequently grouted through these weepers.

Except at Shafts 2 and 4, the concrete was mixed on the surface, lowered on the cages and hauled to the forms in cars of about 1 yard capacity. At each of Shafts 2 and 4, the mixer was placed in the tunnel at the bottom of the shaft, and was fed through a 12-inch wrought iron pipe from storage bins containing the aggregates located at the surface. The cement for a batch was mixed with a small quantity of water and discharged through the pipe and then the aggregates followed. Very good progress was made in concreting the tunnel, from 600 to 1450 feet of completed lining being placed monthly from a single concreting plant. The best record from one plant was made at Shaft 9, where 2394 feet of

sidewall and arch were placed in one month, equivalent to approximately 9500 cubic yards. From 4 to 10 months were spent in placing the lining from each plant.

GROUTING OF TUNNEL

In order to fill all voids over the tunnel arch and back of the lining, grout was forced under low pressure through pipes which were set in the arch at intervals of about 30 feet at the time the concrete was placed. The high vent pipes in the roof, as well as deep seated pipes tapping water-bearing seams were subsequently grouted under a pressure of 250 to 300 pounds per square inch. For low pressure work, a grout of 1 of cement to 1 of sand was generally used, while neat cement was used for high pressure grouting. Air-stirring grouting machines of the Caniff type were employed for grouting, the air pressure being raised for high pressure work by means of portable auxiliary air compressors or "boosters."

SHAFT CLOSURES AND EQUIPMENT

After completion of the concreting and grouting of the tunnel, the shaft closures were made and then the valve chambers were constructed just below the surface of the ground. In the upper portion of each waterway shaft, extending from the floor of the valve chamber down to a depth of at least 100 feet below the top of sound rock, one or two steel riveted pipes were placed and embedded in a concrete plug inside of the shaft lining. These vertical risers are lined with 4 inches of concrete to protect the steel and to make a smooth waterway, with a finished diameter of 4 feet, except that the larger shafts are provided with two 72-inch risers. These risers were each capped by a bronze tee or shaft cap, solidly anchored into the concrete of the shaft plug. This cap has two lateral outlets, to which either 30 or 48-inch bronze gate valves are connected. The bronze valves are for emergency use as valves of the ordinary bronze mounted cast iron pattern are installed next to the bronze gate valves for service operation. On bypass lines around the iron valves, 16-inch pressure regulating valves have been set, wherever water is to be supplied at pressure below the Catskill gradient. A view of one of the larger shaft caps and connecting valves taken in the chamber at Shaft 23 is shown on Plate

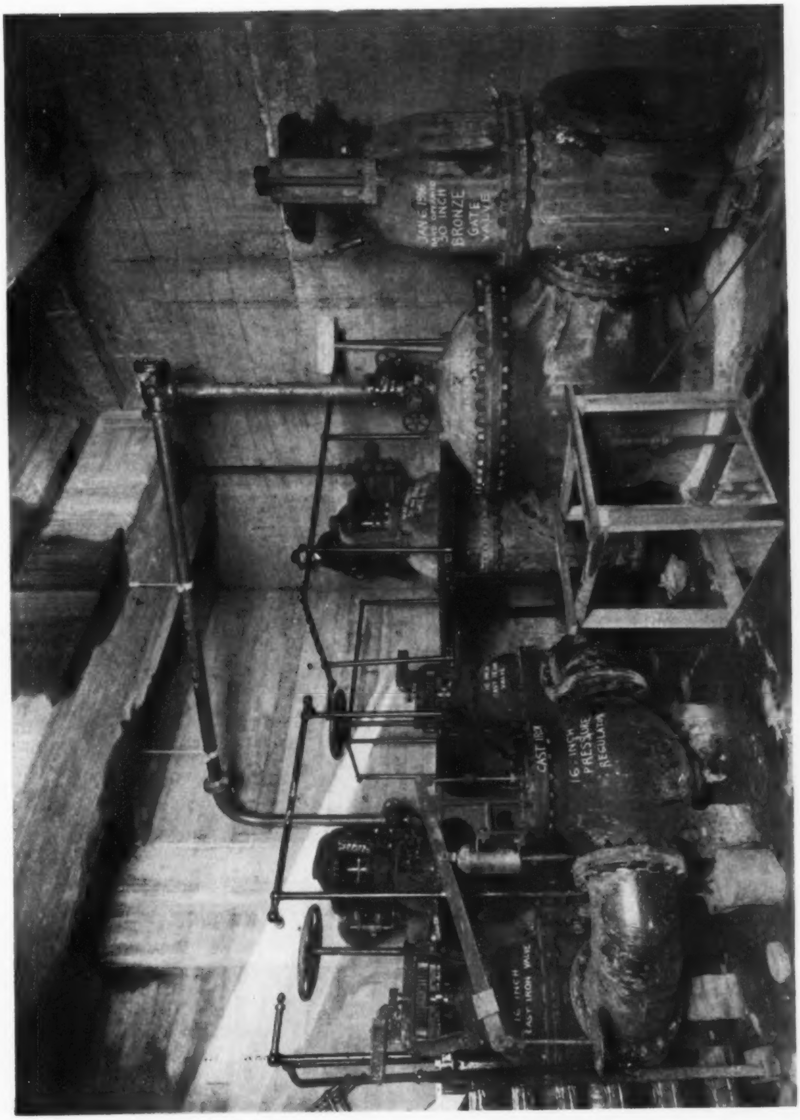


PLATE VII

VII. Venturi meters to measure the discharge in the connecting lines will also be placed in these chambers.

As an additional safeguard against the possible breaking of surface connections, a most interesting and unusual device was adopted to cut off the discharge through the shaft. A valve set at the bottom of each riser is designed to close automatically when the velocity in the riser exceeds a maximum for which the operating mechanism is set. The moving part of this riser valve, which in its exterior form resembles a needle valve, is a tight cylinder moving on a fixed piston, the cylinder communicating with the surface through a small pipe by which the operation of the valve is controlled.

TESTING OF TUNNEL

Upon the completion of contract work the city tunnel was subjected to hydrostatic tests under the full pressure corresponding to the level of the water in Hill View reservoir at elevation 295. The outward leakage under this maximum service pressure from the two northerly sections of the tunnel, 13½ miles in length between Hill View reservoir and Shaft 18 at 25th Street, on which the average unbalanced head was about 225 feet, was approximately 400 gallons per minute, or an average of about 30 gallons per minute per mile, after the full pressure had been maintained for several weeks. On the lower 4½ miles of tunnel, the hydrostatic test developed a somewhat higher rate of leakage, and the tunnel lining after unwatering showed slight cracking in a stretch of about 1000 feet where the pressure had apparently slightly compressed the rock. While the amount of leakage in this section of the tunnel would not at all have been considered serious outside of the city, it was deemed advisable to make the lining in the city as tight as possible, and a contract was accordingly awarded for lining with sheet copper the stretch affected.

A temporary supply from 20,000,000 to 50,000,000 gallons per day from the Catskill sources has been furnished to the borough of The Bronx since the first of the year and it is planned to put the entire tunnel into service with other portions of the Catskill Aqueduct before the close of 1916 when a supply of 250,000,000 gallons per day from Esopus Creek will be available. The introduction of the Catskill supply will permit the suspension of the expensive

pumping plants in the boroughs of Brooklyn, Queens and Richmond, largely cut down the present pumping in the boroughs of The Bronx and Manhattan and greatly improve the pressure in many sections of the city. The present gravity sources supplying Manhattan and The Bronx boroughs, namely the Croton, Bronx and Bryam supplies, will continue to furnish water for the low services and a portion of the higher services in these boroughs, but in other portions of the city the present pumped supplies will be temporarily abandoned and held in reserve for future needs.

COST

Data in regard to the cost of the city tunnel follow. The major contracts have been entirely completed, but superstructures have not yet been erected and some equipment remains to be placed, so that the figures for these items are not final but are substantially correct.

Preliminary Investigations:		
Borings, Contracts 38, 73, 98	$171,942	
Surveys and studies	189,357	$361,299
Real Estate:		
Awards for tunnel easement and shaft property	314,414	
Expenses of condemnation	35,904	350,318
Construction:		
Tunnel Contracts 63, 65, 66 and 67	$18,415,000	
Equipment contracts	880,000	
Superstructures	150,000	
Engineering	950,000	20,395,000
		$21,106,617

The unit costs of the several sizes of tunnel based on the estimated final quantities and the contract prices, and exclusive of preliminary work, real estate, superstructures and engineering, are shown in the following table:

Estimated cost of the city tunnel

DIAMETER OF TUNNEL	LENGTH OF TUNNEL	NUMBER OF SHAFTS		DEPTH OF SHAFTS			COST OF TUNNEL PER LINEAR FOOT	
		For construction only	For waterway, access and drainage	Minimum	Maximum	Total	Tunnel only	Total including shafts and equipment
feet	*feet*			*feet*	*feet*	*feet*		
15	38,926	1	8½*	218	477	2,910	$146	$195
14	26,247	0	7	220	447	1,954	151	202
13	4,554	0	1	204	224	214	146	182
12	9,080	0	2	204	749	1,005†	141	204
11	15,096	0	4½*	318	757	2,305†	139	249

* Where tunnel diameter changes, one-half cost of shaft is charged to each size tunnel.

† Lengths of tunnel and depths of shafts are according to original profile on which payment is based.

INTERPRETATION OF WATER WORKS ACCOUNTS

By Mark Wolff

Certified Public Accountant

The author has met officially several members of this association, while examining the books and accounts of several water companies supplying certain districts of New York City, in connection with valuations for the readjustment of some of the rates and the establishment of an equitable basis for probable ultimate purchase of these plants by the city. During this work suggestions were asked for improving existing accounting systems of both office and field. During these inquiries attention was called to the pamphlet published by the Bureau of the Census, entitled "Uniform Accounts for Water Works," which, though considered a creditable work, has not proven successful from the standpoint of practicability. The difficulty seemed to be that it requires someone with extensive experience in water works accounts to devise and correctly install, with requisite forms, an appropriate system of accounts fitted to the individual requirements of a particular company. After a study of the census classification the author concluded that, while the accounts set forth are to all intents and purposes complete and scientific, they are by far too elaborate for a works of average size, and therefore not readily understood by the average superintendent of a water plant.

The introduction to the Census classification contains, among others, the following remarks:

> The annual revenues of different water works vary from less than $1000 to over $10,000,000 per annum, and their assets vary from less than $10,000 to over $150,000,000. The number of accounts that are required, or that can be used to advantage for administrative purposes by any enterprise, must vary with the volume of business and assets; and hence a uniform system of accounts must first of all be adjustable to the requirements of large and small enterprises. . . .

In the formulation of any standard system of accounts, provision must be made for the largest unit of the particular class of enterprise dealt with. For that reason, it was necessary to allow suffi-

cient accounts for a system such as New York City's, with revenues of about $13,000,000 and assets of over $250,000,000. The same holds true of the cities of Chicago and Philadelphia. However, these three are the only cities which have a population of over a million, according to the 1910 census. This census lists the following number of cities with populations of 25,000 or over.

POPULATION	NO. OF CITIES	PER CENT
Over 1,000,000	3	1.4
From 200,000 to 999,999	25	10.9
From 100,000 to 199,999	22	9.6
From 25,000 to 99,999	179	78.1
	229	100.0

For the sake of comparison, it will be assumed, that there is but one water works system in a city. On this basis, allowing annual revenues of $2 per capita of population, there would be only twenty-eight systems in the United States earning over $400,000 total revenues per annum, or less than one-eighth of the largest cities in the country. The Census classification, being practically complete, is ideal for just such systems, with large revenues and extensive assets. Of course, no account is taken of the separate provision which would have to be made to meet the special budgetary and fund account requirements of practically all of the larger municipalities, of which nearly all of the twenty-eight shown above own and operate the water works systems.

A water plant capable of supplying 1,000,000 people would as an engineering proposition, of course, be considered too elaborate for a city of 100,000. The physical plants would be different in both cases. The same holds true of an accounting system arranged to record financially and statistically the operations and development of such an enterprise. Therefore, it will be necessary to plan a less elaborate set of accounts for the remaining 201 cities shown in the above table, as well as for the smaller cities not included above, which comprise the majority in the country.

As the engineering requirements of a water works will depend chiefly on the amount of population to be served and as the necessary accounting system will have to conform with the physical characteristics of the plant as laid out by the engineering department, the following classification based on population of cities and villages is made.

Class A	Population from 1,000 to 10,000
Class B	Population from 10,001 to 25,000
Class C	Population from 25,001 to 200,000
Class D	Population over 200,000

This paper will deal only with Class A and Class C. The accounting requirements of water works coming under Class B can readily be determined by modifying the accounts prescribed for Class C or augmenting those of Class A. No attempt will be made to set up accounts for the twenty-eight cities comprising Class D.

CLASS A

Plants supplying a territory with less than 10,000 population will, as a rule, require the most simple set of accounts. Such water works could well adopt simply the ten accounts of a single order mentioned by the Census Bureau. These accounts are as follows:

0. Water Service Revenues.
1. General Expenses.
2. Operating Expenses.
3. Maintenance Expenses.
4. Miscellaneous Revenues and Expenses.
5. Profit and Loss.
6. Fixed Assets and Funds.
7. Current and Nominal Assets.
8. Proprietary Interests.
9. Liabilities.

The contents of the above accounts may be described as follows:

0. Sale of water.
1. Overhead expenses.
2. Costs of labor, supplies and expenses used directly for operation of plant.
3. Costs of repairs and losses through depreciation.
4. All revenues and expenses not directly dependent upon service of water.
5. The summing up of preceding accounts, to determine net profit or loss of enterprise.
6. Actual cost of permanent property (fixed assets) and record of special funds.
7. Working capital of enterprise used for current operations.
8. Amount of proprietary interest in enterprise, which will agree with the sum of accounts 6 and 7 (assets) less account No. 9 (liabilities).
9. The recording of the obligations of the enterprise.

It will be seen from the above that these accounts have been arranged in the same order as they appear in the Census Classification, although it would be more logical to have assets and liabilities at the top of the list, as they relate chiefly to investment and construction which precede operation. The latter is represented by the remaining, or revenue and expense, accounts. In most instances, there would be little, if any, occasion to use the revenues and expense accounts until the original construction were well under way or completed, and operation of the plant commenced. Accordingly, the discussion will be commenced by referring first to the asset and liability, or indicant, accounts. To this end, these accounts are assembled into a Balance Sheet. The figures used here, as well as in all other parts of this article, are, of course, not taken from the books of any particular works. They are, further, mere approximations and are not guaranteed as to being always representative in amount. Such theoretical figures are used merely for the purpose of illustration.

BALANCE SHEET

ASSETS		
Fixed	$40,000	
Current	10,000	
Total		$50,000
LIABILITIES		15,000
PROPRIETARY INTERESTS		$35,000

The interrelationship of these accounts can be determined from the Balance Sheet shown above. But, simple as that may be to an accountant, it will not afford the same perspective to the eye of the engineer as a graphic chart. Accordingly, this Balance Sheet is expressed in the form of a diagram, as shown in Diagram No. I.

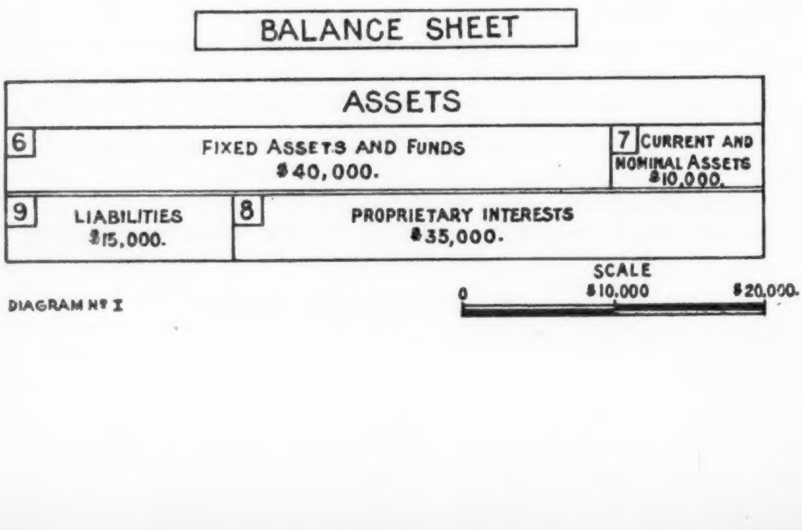


DIAGRAM Nº I

It is seen from the diagram that the Balance Sheet is a statement of financial condition, showing in this case two classes of assets, provided for by accounts 6 and 7, against which are measured the liabilities and proprietorship contained in accounts 8 and 9. This diagram indicates that the total of assets is equal to the liabilities plus proprietorship, as expressed by the following equation:

$$\text{Assets} = \text{Liabilities} + \text{Proprietary Interests.}$$

This equation is constantly present in double entry bookkeeping, which is the basis of all modern accounting. It may also be expressed in another way, to wit:

$$\text{Assets} - \text{Liabilities} = \text{Proprietary Interests.}$$

The diagram shows not only the relationship of the accounts, but also purports to show with approximate accuracy the relative financial value of each of its components, as expressed by the space allotted to the individual accounts.

Let us for a moment speculate as to what details support the accounts shown by the Balance Sheet. Fixed assets might consist of landed or nonlanded, tangible or intangible property; current assets might consist of cash, accounts receivable, notes receivable, investments, etc. The liabilities might be long term, or fixed, or short term, floating. A Balance Sheet in the form of the one under discussion opens up quite a wide field of speculation, a rather dangerous experiment from the standpoint of the several parties at interest in a larger enterprise. In such an enterprise, it is therefore necessary to have the accounts in more detail, so that as little as possible is left to the imagination. A statement of financial condition showing this necessary detail is shown in diagram No. III representing a Balance Sheet for water works in Class C, to be more particularly referred to later in this paper.

The purpose of accounting is to show:

(1) The condition of the business. (2) The progress of the business.

The first purpose, that of condition, has already been fulfilled in the Balance Sheet described hereinbefore. The second purpose, that of progress, is indicated by the Income Account. The accounts comprising it are in accordance with the Census Classification for small companies, classed as A.

INCOME ACCOUNT

REVENUES		
Water service	$8,000	
Miscellaneous	2,000	
Total revenues		$10,000
EXPENSES		
General	$1,500	
Operation	3,000	
Maintenance	2,000	
Miscellaneous	500	
Total expenses		7,000
Profit to proprietary interests		$3,000

This arranged in diagram form is as follows:

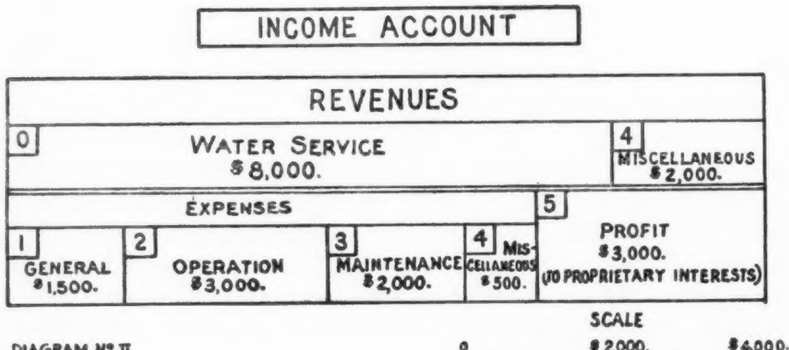


DIAGRAM Nº II

The diagram consists of two parts, one revenues, against which is applied the second part, expenses, the difference being the profit for the period.

Expressed algebraically, this diagram would make this equation:

$$\text{Revenues} = \text{Expenses} + \text{Profit}$$

or

$$\text{Revenues} - \text{Expenses} = \text{Profit}$$

The revenues are divided into two parts, water service and miscellaneous; the expenses into four, general, operation, maintenance and miscellaneous. Space is allotted to the various accounts practically according to scale. As the Income Account shows the progress of the business, its components are a temporary set of accounts, sometimes called economic, which collectively record the changes

in the net wealth due to the business operations of a stated period, usually the fiscal year. The result shown by this account is necessarily transferred to the proprietary interests; if a profit, it is added thereto; if a loss, it is subtracted therefrom. Therefore, since the proprietary interests absorb the results of the income account, it has two components, as follows:

Proprietorship = Capital at beginning of period + Profit during period

or

Proprietorship = Capital at beginning of period − Loss during period.

The result of the Income Account, transferred to the proprietary interests at the end of the fiscal year, will change the Balance Sheet, or, in other words, show a condition different from that at the beginning of the fiscal year. Therefore a complete equation of the Balance Sheet will be:

Assets = Liabilities + Proprietorship (at beginning) + Gain (or − Loss).

Since the Income Account shows progress or recession of the past, the administrator should be able to obtain valuable information from it, for his future guidance. The work of profiting from past experience in a water works belongs almost exclusively to the operating engineer, but accountancy will go a long way towards helping the engineer. The latter, already having the characteristics of the physical plant at his fingers' tips, so to speak, will be able to estimate what the approximate cost of operation should be. An adequate classification of accounts, supported by a properly installed and efficiently administered system of office and field records will enable him to check up his estimates in sufficient detail, so that he may quickly locate points at which economies can be effected, etc.

The Income Account shown in diagram No. 1 does not provide the detail necessary to enable the engineer to properly administer and operate a plant of any magnitude. It is not sufficient for him to know in a lump sum, using the figures in the chart, that the general expenses were $1500, cost of operation $3000, maintenance $2000 and miscellaneous $500. These figures would of course be useful to some extent, but he would also want to know the details of which they are comprised. For example, under operation, he would, for a water system of any size, want to know the total cost of pumping; how much of this cost was expended for labor, how much for fuel, how much for oil, packing, waste, etc., so that he may be able to complete his pumping efficiency records and determine the total consumption of coal, the average cost per ton, the average

million foot pounds per 100 pounds of coal and also the total cost per million gallons raised one foot. Under maintenance, it would be desirable to know what was the total cost of repairs to the distribution system, how much for mains, hydrants, meters, standpipe, etc. All these, and more, facts would not only aid materially in locating waste and effecting economies, but would be essential to the establishment of a proper charge for domestic service and fire protection. This thought could be pursued further, but will assume that at least sufficient reasons have been given why the Income Account should be augmented in a larger organization, just as it has been shown why the Balance Sheet for the smallest water works would not do for larger enterprises.

This leads us up to the point where the accounting requirements of the next class (C) are to be considered. It will be remembered that accounts are not to be prescribed for Class B, as that can readily be done by the reader, with the aid of Classes A and C. That portion of the foregoing remarks which relates to general accounting principles, of course, applies also to what follows. It is therefore unnecessary to repeat the theory of the Balance Sheet and Income Account; in fact, the mention of it in the first place was made with hesitation, but, on second consideration, it was decided to incorporate it, since it may help some to a better understanding of the subject.

CLASS C

Water works serving a population of from 25,000 up will naturally require a more extended classification than is provided by the ten accounts of a single order prescribed by the Census Bureau for small companies; in fact, as hereinbefore stated, such a small number of accounts will undoubtedly be found inadequate for water works in Class B, serving a population from 10,000 to 25,000.

The following Condensed Balance Sheet is intended for companies in Class C. It is arranged to some extent in compliance with the general classification prescribed by public utility commissions.

Balance Sheet

Assets

Fixed Capital				
Landed		$75,000		
Non Landed				
Tangible	$2,125,000			
Intangible	150,000	2,275,000	$2,350,000	
Floating Capital			140,000	
Miscellaneous			10,000	
Total Assets				$2,500,000

Liabilities

Funded Debt	$1,000,000	
Deposits	75,000	
Prepayments	30,000	
Floating Debt	120,000	
Total Liabilities		1,225,000
Proprietorship		$1,275,000

Proprietorship

Capital Stock	$1,200,000
Reserves for Extensions and Betterments	15,000
Surplus and Undivided Profits	10,000

This is shown in diagram form on the following page.

It will be seen that the above Balance Sheet in both ordinary and diagram form consists of general accounts representing summaries of specific assets, liabilities, etc. The necessary detailed accounts will be found on pages 539–41 in ordinary form and opposite page 540 in diagram form. While the diagram shows a scale, not all parts of it are strictly in accordance with that scale. But with a little study the eye of an engineer will see more in diagram IV than in the ordinary form of Balance Sheet.

The preceding accounts are representative of what one might expect to find in a water works of this class. By that it is not meant that all such plants will have these exact accounts. Some may have more: others less. This form is intended as a suggestion. With it as a working basis and with a particular local situation in mind, what little excess there may be for a particular company can easily be eliminated and any deficiency can readily be supplied. The accounts here shown are based partly on the requirements of

BALANCE SHEET

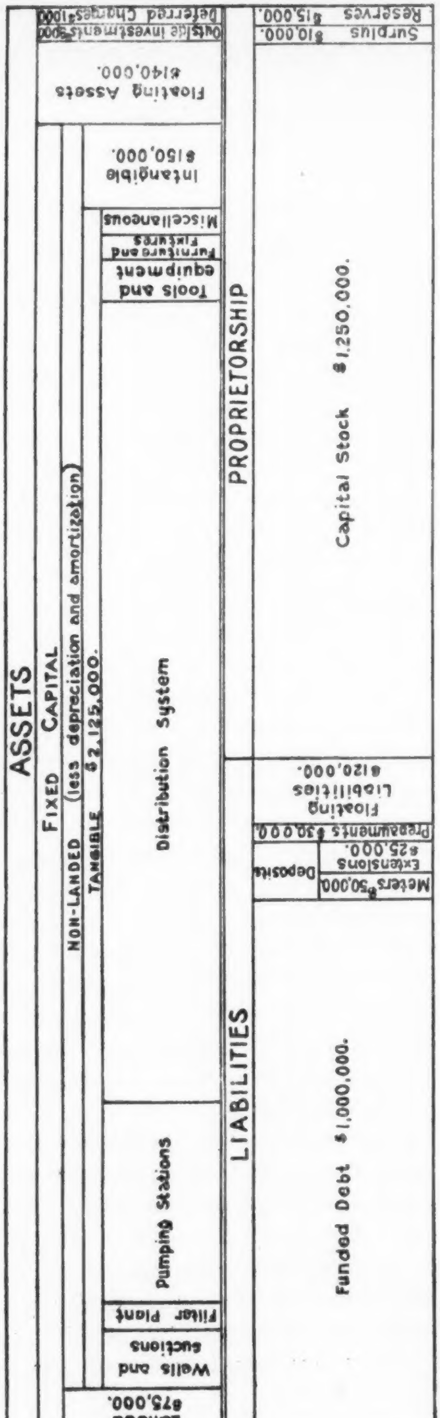


DIAGRAM Nº III

public utility commissions and largely on the author's personal experience in public and private water works.

The diagram is arranged in two parts, upper and lower. The upper portion is the same as diagram III on which the scale runs horizontally. The lower portion of the chart is a box divided in half by a double vertical line running down the center. It contains data supporting the upper chart. To the left are shown assets, corresponding to the top part of the upper chart, and, to the right, liabilities and proprietorship, corresponding to the bottom part of the upper diagram. In the lower diagram each division contains the same general accounts as are shown on the part of the upper chart which it represents, but in addition it also shows detailed accounts, together with amounts; for example, above is shown, under "Non Landed Intangible Capital" the item of "Pumping Stations" below this same account is shown, but divided into four parts, buildings and chimneys, boiler plant, pumping machinery and miscellaneous station equipment: among the liabilities the upper diagram shows floating liabilities, but in the lower portion this is divided into notes payable, accounts payable, interest, etc.

Balance Sheet of X. Y. Z. Water Company

As at April 30, 1916

Assets

Fixed Capital			
Landed			
Water supply sources and works		$62,500	
Embankments, ditches, roads, etc		10,000	
Other lands		2,500	
Total			$75,000
Non Landed			
Tangible			
Wells and suction		$100,000	
Filter plant		50,000	
Pumping stations			
Buildings and chimneys	$75,000		
Boiler plant	50,000		
Pumping machinery	200,000		
General station equipment	25,000	350,000	
Distribution system			
Mains and appurtenances	$1,500,000		
Hydrants and connections	150,000		
Meters and fittings	75,000		
Standpipe	20,000		
Fountains, troughs, etc	5,000	1,750,000	

Tools and implements		$50,000	
Furniture and fixtures		15,000	
Miscellaneous tangible capital (Maps, plan books, etc.)		10,000	
		$2,325,000	
Less depreciation to date		200,000	$2,125,000
Intangible			
Cost of franchise rights		$75,000	
Promotion and organization		50,000	
Unamortized debt discount and expense		75,000	
		$200,000	
Less amortization to date		50,000	150,000
TOTAL FIXED CAPITAL			$2,350,000
FLOATING CAPITAL			
Cash		$40,000	
Notes receivable		15,000	
Accounts receivable			
Current year	$50,000		
Prior years	15,000		
	$65,000		
Less reserve for doubtful accounts	5,000	60,000	
Inventories			
Coal	10,000		
Material and supplies	5,000	15,000	
Other floating capital		10,000	
TOTAL FLOATING CAPITAL			140,000
Investments in outside enterprises			9,000
Deferred charges			1,000
			$2,500,000

Liabilities

FUNDED DEBT			
Mortgage Bonds			$1,000,000
Consumers' Deposits			
Meter deposits		$50,000	
Extension guarantees		25,000	75,000
Prepayments			
Water rates paid in advance			30,000
FLOATING LIABILITIES			
Notes payable		$12,500	
Accounts payable		30,000	
Interest accruals			
on bonds	$12,500		
on notes	500		
on taxes	1,000	14,000	
Accrued taxes		25,000	
Accrued income tax on bond coupons		1,000	
Dividend declared (semi-annual)		37,500	
TOTAL FLOATING LIABILITIES			120,000

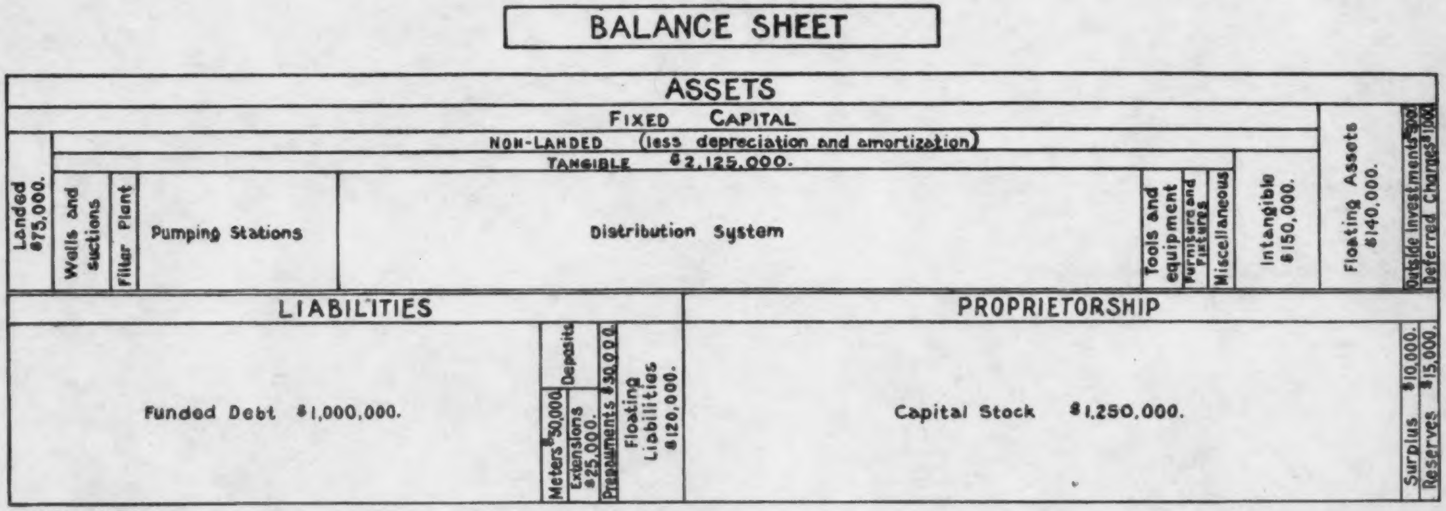


DIAGRAM No III

...ETS / CAPITAL / ...uct depreciation and amortization) / TANGIBLE / ...ystem		$	
Landed	Water Supply, sources and works	62500	
	Embankments, ditches, roads, etc.	10000	
	Other lands	2500	75000
	Wells and Suctions		100000
	Filter Plant		50000
Pumping Stations	Buildings and Chimneys	75000	
	Boiler Plant	50000	
	Pumping Machinery	200000	
	Miscellaneous station equipment	25000	350000
	Mains and appurtenances	1500000	

LIABILITIES		$	
	Funded Debt (Mortgage Bonds)		1000000
Consumers Deposits	Meter deposits	50000	
	Extension guaranties	25000	75000
	Prepayments - water rates paid in advance		30000
Floating Liabilities	Notes payable	12500	
	Accounts payable	30000	
	Interest Accruals On Bonds	12500	
	Interest Accruals On Notes	500	
	Interest Accruals On Taxes	1000	
	Accrued Taxes	25000	
	Accrued income tax on bond coupons	1000	
	Dividend declared (Semi-annual)	37500	120000

ASSETS

FIXED CAPITAL

NON-LANDED (Deduct depreciation and amortization)

TANGIBLE

Pumpin[g]	Miscellaneous station equipment	25000	350000
Distribution System	Mains and appurtenances	1500000	
	Hydrants and connections	150000	
	Meters and fittings	75000	
	Standpipe	20000	
	Fountains, troughs and other equipment	5000	1750000
	Tools and implements		50000
	Furniture and fixtures		15000
	Miscellaneous		10000
			2325000

LIABILITIES

Consumers Deposits	Meter deposits	50000	
	Extension guaranties	25000	75000
	Prepayments - water rates paid in advance		30000
Floating Liabilities	Notes payable	12500	
	Accounts payable	30000	
	Interest Accruals On Bonds	12500	
	Interest Accruals On Notes	500	
	Interest Accruals On Taxes	1000	
	Accrued Taxes	25000	
	Accrued income tax on bond coupons	1000	
	Dividend declared (Semi-annual)	37500	120000

PROPRIETORSHIP

Capital Stock	1250000

		Fountains, troughs and other equipment	[illegible]	[illegible]
		Tools and implements		50000
		Furniture and fixtures		15000
		Miscellaneous		10000
				2325000
		Less depreciation		200000
				2125000
	INTANGIBLE	Cost of franchise rights	75000	
		Promotion and Organization	50000	
		Unamortized debt; discount and expense	75000	
			200000	
		Less amortization	50000	150000
FLOATING CAPITAL		Cash	40000	
		Notes receivable	15000	
		Accounts receivable	60000	
		Inventories (Coal, Material and supplies)	15000	
		Other floating capital	10000	140000
		Investments in outside enterprises		9000
		Deferred charges - Unexpired insurance		1000
		GRAND TOTAL		2500000

PROP

Surplus and undivided profits	10000
Reserve for extensions and betterments	15000
GRAND TOTAL	2500000

SCALE
0 $250,000 $500,000

Mark Wolff
CERTIFIED PUBLIC ACCOUNTANT
1328 BROADWAY
NEW YORK CITY

DIAGRAM No IV

Proprietorship

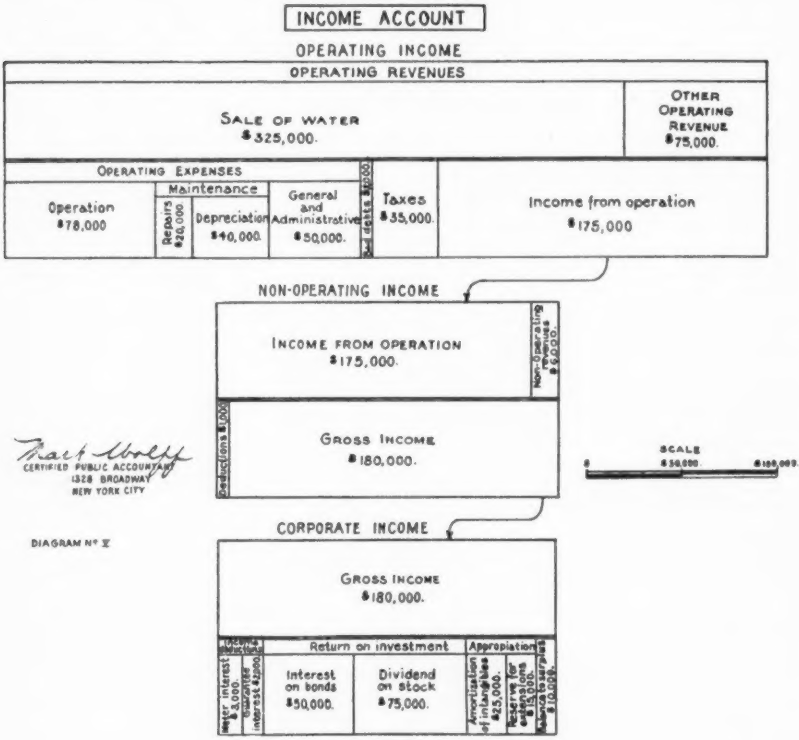
Capital Stock	$1,250,000
Surplus and undivided profits	10,000
Reserve for extension and betterments	15,000
	$2,500,000

The following is a summarized Income Account of the theoretical water works whose Balance sheet is shown immediately preceding.

INCOME ACCOUNT

OPERATION		AMOUNT		PER CENT	
Operating Revenues					
Sale of water		$325,000		81.25	
Other operating revenues		75,000		18.75	
Total Operating Revenues			$400,000		100.00
Operating Expenses					
Operation		$78,000		19.50	
Maintenance					
Repairs and replacements	$20,000				
Depreciation	40,000	60,000		15.00	
General and administrative		50,000		12.50	
Total Operating Expenses			188,000		47.00
			$212,000		53.00
Bad Debts		$2,000		0.50	
Taxes		35,000	37,000	8.75	9.25
INCOME FROM OPERATION			$175,000		43.75
NON OPERATION					
Non operating revenues		$6,000			
Non operating revenue deductions		1,000	5,000		1.25
GROSS INCOME			$180,000		45.00
CORPORATE INCOME					
Income Deductions			5,000		1.25
			$175,000		43.75
Return on investment		$125,000		31.25	
Appropriation of income		40,000	165,000	10.00	41.25
BALANCE TO SURPLUS			$10,000		2.50

The summary Income Account is here shown in diagram form arranged in three parts, entitled "Operating," Non Operating" and "Corporate" Income respectively.



The first section will be found most interesting to the operating engineer, the second relates mainly to financing and the third will be the first place to strike the eye of the investor. Each of these three sections is shown individually in the requisite detail with the usual supporting accounts on three separate charts; opposite which will be found, in ordinary accounting form, that portion of the Income Account which relates thereto. The three detailed diagrams will be found on pages 545, 549 and 550.

The first section, Operating Income Account, which is of greatest interest to the superintendent, will be found to contain the sources of operating income and objects of operating expenditure. As in the Balance Sheet, the amounts represented are estimated and

are not based on the operations of any particular water works. Although these figures are assumed, they will nevertheless be found interesting.

Take, for example, the relationship between revenues from metered and unmetered service. In this case, they are both of equal amount, which, of course, does not necessarily mean that each represents the same amount of consumption. This is said having in mind particularly the experience of the City of New York, whose revenues from both kinds of services are about equal, but whose consumption through meters is only 27 per cent of the total amount of water consumed, lost and wasted. The question of the relatively small amount of water waste under the meter system as compared with the wastage on a flat rate basis is here automatically suggested. In this connection, the City of New York has just had a bill introduced in the legislature the passing of which will mean that eventually the entire city will be metered. Then, getting back to the Income Account, note the amount of revenues derived from fire protection, erroneously called hydrant rentals by some, and compare with total revenues. This percentage, 18, will, of course, vary in different water works, according to peculiar local conditions. A case in point is that of the Queens County Water Company, on which the author assisted Deputy Commissioner Delos F. Wilcox in his valuation and rate investigation. Fire protection will again be referred to, treating it as a separate topic on account of its importance.

Under operating expenses, no doubt some of you will find something to say regarding the ratio between the expenditures for operation and maintenance of the various parts of the plant compared with the assets shown by the Balance Sheet, as well as the ratio between one kind of expense and another. The item of "depreciation" on various parts of the plant as shown in the Income Account ought to stimulate discussion.

Following is the estimated life of the various assets used in arriving at the annual depreciation shown in the Income Account: horses, carriages and motors, 10 years; office furniture and general equipment, 15 years; boilers, steam pipes, filters, 20 years; pumping machinery and engines, 25 years; mains, fire hydrants, standpipes, buildings, masonry, 50 years; reservoirs, aqueducts, 100 years.

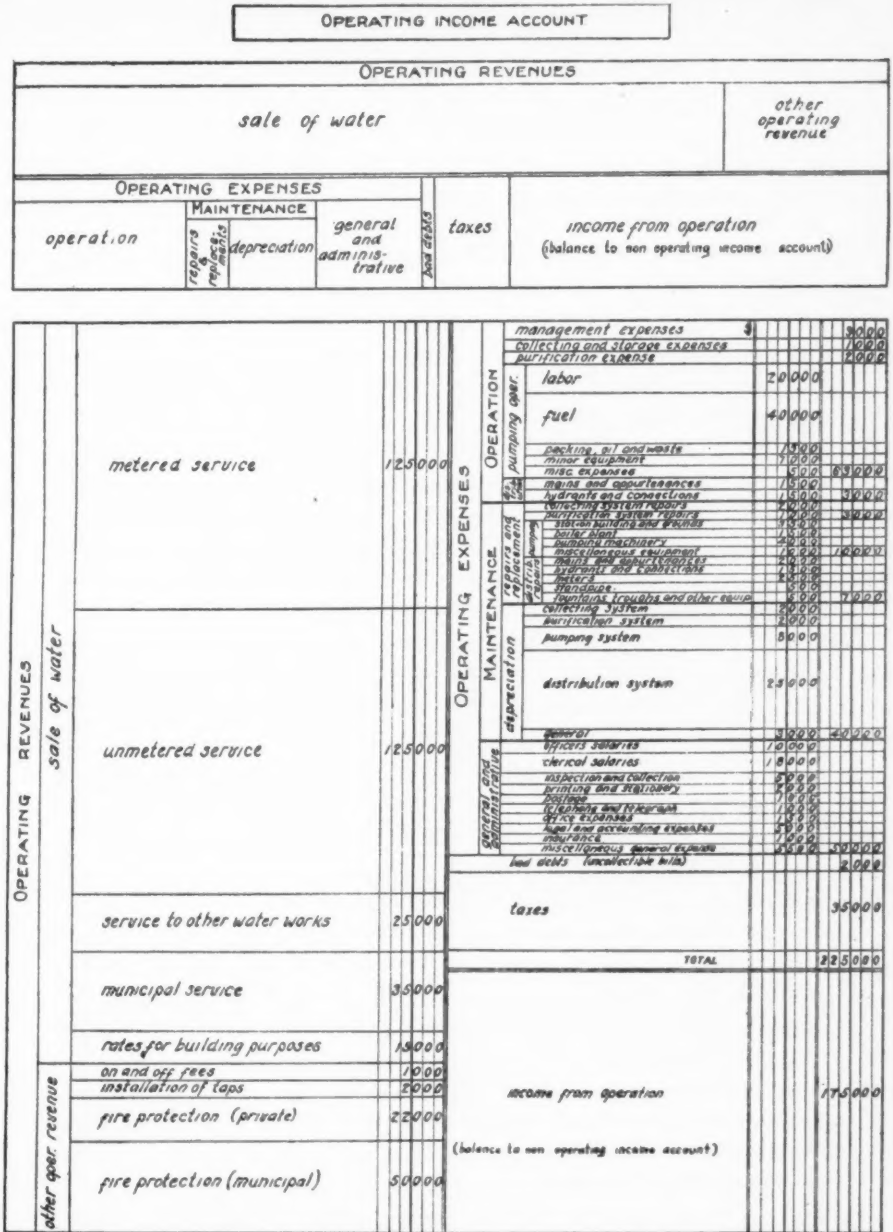
The following three pages contain, in both ordinary and diagram form, the Operating section of Income Account referred to above.

Income Statement of the X. Y. Z. Water Company

Period, May 1, 1915, to April 30, 1916

Operating Income Account

						PER CENT OF TOTAL OPERATING REVENUES $400,000.00
OPERATING REVENUES						
Revenues from water service						
Metered service			$125,000			31.25
Unmetered service			125,000			31.25
Service to other water works			25,000			6.25
Municipal service			35,000			8.75
Rates for building purposes			15,000	$325,000		3.75
Other operating revenues						
On and off fees			$1,000			0.25
Installation of taps			2,000			0.50
Fire protection—private			22,000			5.50
Fire protection—municipal			50,000	75,000		12.50
TOTAL OPERATING REVENUES					$400,000	100.00
OPERATING EXPENSES						
Operation						
Management expenses		$9,000				2.25
Collecting and storage expenses		1,000				0.25
Purification expenses		2,000				0.50
Pumping expenses						
Labor	$20,000					5.00
Fuel	40,000					10.00
Packing, oil and waste	1,500					0.37
Minor equipment	1,000					0.25
Miscellaneous	500	63,000				0.13
Distribution expenses						
Mains and appurtenances	$1,500					0.37
Hydrants and connections	1,500	3,000				0.38
Total operation				$78,000		19.50
Maintenance						
Repairs and Replacements						
Collecting and storage		$2,000				0.50
Purification		1,000				0.25



Mark Wolff
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NEW YORK CITY

DIAGRAM No VI

SCALE
0 $50,000. $100,000.

Pumping Stations						
Buildings and grounds....	$3,500					0.87
Boiler plant..	1,500					0.38
Pumping machinery	4,000					1.00
Miscellaneous equipment.	1,000	$10,000				0.25
Distribution						
Mains and appurtenances	$2,000					0.50
Hydrants and connections.......	1,500					0.37
Meters.......	2,500					0.63
Standpipes...	500					0.13
Fountains, troughs, etc.	500	7,000				0.12
Total Repairs and Replacements.			$20,000			5.00
Depreciation						
Collecting and storage system.............		$2,000				0.50
Purification system....		2,000				0.50
Pumping system......		8,000				2.00
Distribution system...		25,000				6.25
General..............		3,000				0.75
Total Depreciation...............			40,000			10.00
Total maintenance..........................				$60,000		15.00
General and administrative						
Officers' salaries.................			$10,000			2.50
Clerical salaries..................			18,000			4.50
Inspection and collection.........			5,000			1.25
Printing and stationery..........			2,000			0.50
Postage..........................			1,000			0.25
Telephone and telegraph.........			1,000			0.25
Office expenses..................			1,500			0.37
Legal and accounting expenses...			5,000			1.25
Insurance.......................			1,000			0.25
Miscellaneous....................			5,500			1.38
Total general and administrative.............				50,000		12.50
TOTAL OPERATING EXPENSES..........................					$188,000	47.00
					$212,000	53.00
Uncollectible bills.............................				$2,000		
Taxes..				35,000	37,000	9.25
INCOME FROM OPERATION............................					$175,000	43.75

As stated hereinbefore, the second section of the Income Account relates mainly to finances. One item therein, penalties on accounts receivable, $2000, is suggestive. It is the opinion of the author that all private water companies, particularly those controlled by a Public Service Commission or other regulatory body, should have the right to charge penalties on accounts receivable, especially since, unlike the municipal plant, they do not as a rule have a lien against the property as insurance against loss through non payment. In the matter of liens, one of the companies in New York City has adopted, with considerable success, a rather clever, if not original, device for obtaining a lien against property. This is accomplished by adding to the regular form of application for service a clause whereby the owner agrees to the lien. The filing of a duplicate of the application in the County Clerk's office makes the application in effect a lien on the property. The absence of the security afforded by a lien is particularly embarrassing in some cases for the water company; a case in point, in the experience of another company. A certain real estate company owned the fee in a private street which had not been dedicated to the city. The realty company failed, the mortgagees foreclosed and, by virtue of their prior lien against the property, obtained possession of the street. The water company had an easement through this street, but the mortgagees had priority and the foreclosure of the mortgage wiped out this easement, at least so the mortgagees claim. This point is disputed by the water company and it is more than likely that the latter will win, but only after considerable annoyance and expense through litigation. If the mortgagees should win, the title to all the pipe in the street, laid at the water company's expense, would vest in the mortgagee. In this case, if the water company possessed a lien against this property, it not only would have collected the water bill against the realty company, but a dispute such as this would have been impossible. If public policy is against the granting of a lien to a public utility conducted for profit, then the company should at least be allowed to impose penalties for delinquent payment on account. The imposition of penalties would greatly reduce the losses through bad debts. The second, Non Operating, section of Income Account above referred to is shown on pages 548 and 549.

While the third section, "Corporate Income," has general interest, it relates more particularly to the returns on investments of bondholders and stockholders. It shows, besides the profitableness or unprofitableness of the enterprise, the financial policy of the com-

INCOME STATEMENT—*(continued)*

Non Operating

INCOME FROM OPERATION			$175,000
NON OPERATING REVENUES			
Penalties on Accounts Receivable	$2,000		
Interest on Notes Receivable	1,000		
Interest on Bank Balances	1,000		
Interest and Dividends on investments	1,000		
Miscellaneous	1,000	$6,000	
NON OPERATING REVENUE REDUCTIONS			
Interest on Accounts Payable	$500		
Interest on Notes Payable	500	1,000	5,000
GROSS INCOME			$180,000

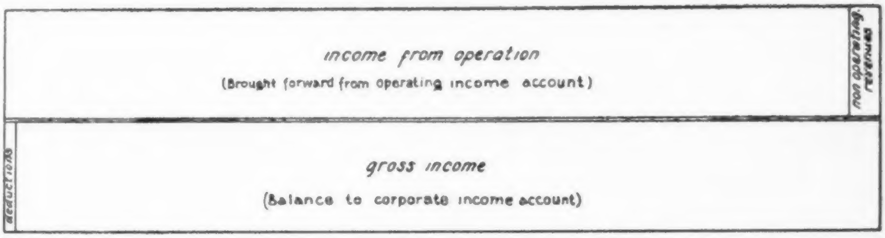
pany. By this the policy of amortizing the intangibles is referred to. In this connection, none of the books of the water companies examined by the author sets aside reserves for extensions and betterments or amortizes intangibles. In this section it is also shown that this theoretical company allows interest on meter deposits, something which is done by only two of the companies whose books have been examined. The extension guaranties, on which interest is also allowed, represent deposits of new consumers, by means of which they induce the water company to extend its mains to new and undeveloped territory. These deposits are returned in instalments as the consumers' water bills grow large enough to justify the company assuming the cost of the extensions. (See page 550 for diagram VIII illustrating the following statement, referred to above.)

INCOME STATEMENT—*(concluded)*

Corporate Income

GROSS INCOME		$180,000
Income Deductions		
Interest on meter deposits	$3,000	
Interest on extension guaranties	2,000	5,000
NET CORPORATE INCOME		$175,000
Return on Investment		
Interest on bonds	$50,000	
Dividends on stock	75,000	125,000
		$50,000
Appropriation of Income		
Amortization of intangibles	$25,000	
Reserve for extensions and betterments	15,000	40,000
BALANCE TO SURPLUS AND UNDIVIDED PROFITS		$10,000

NON-OPERATING INCOME ACCOUNT



income from operation (brought forward from operating income acc't)		175000	deductions: interest on acc'ts payable	500	
			deductions: interest on notes payable	500	1000
non operating revenues: penalties on acc'ts receivable	2000		gross income (balance to corporate income account)		180000
interest on notes receivable	1000				
interest on bank balance	1000				
interest and dividends on investments	1000				
misc non operating revenues	1000	6000			
TOTAL		181000	TOTAL		181000

DIAGRAM Nº VII

SCALE 0 $22,625 $45,250

CORPORATE INCOME

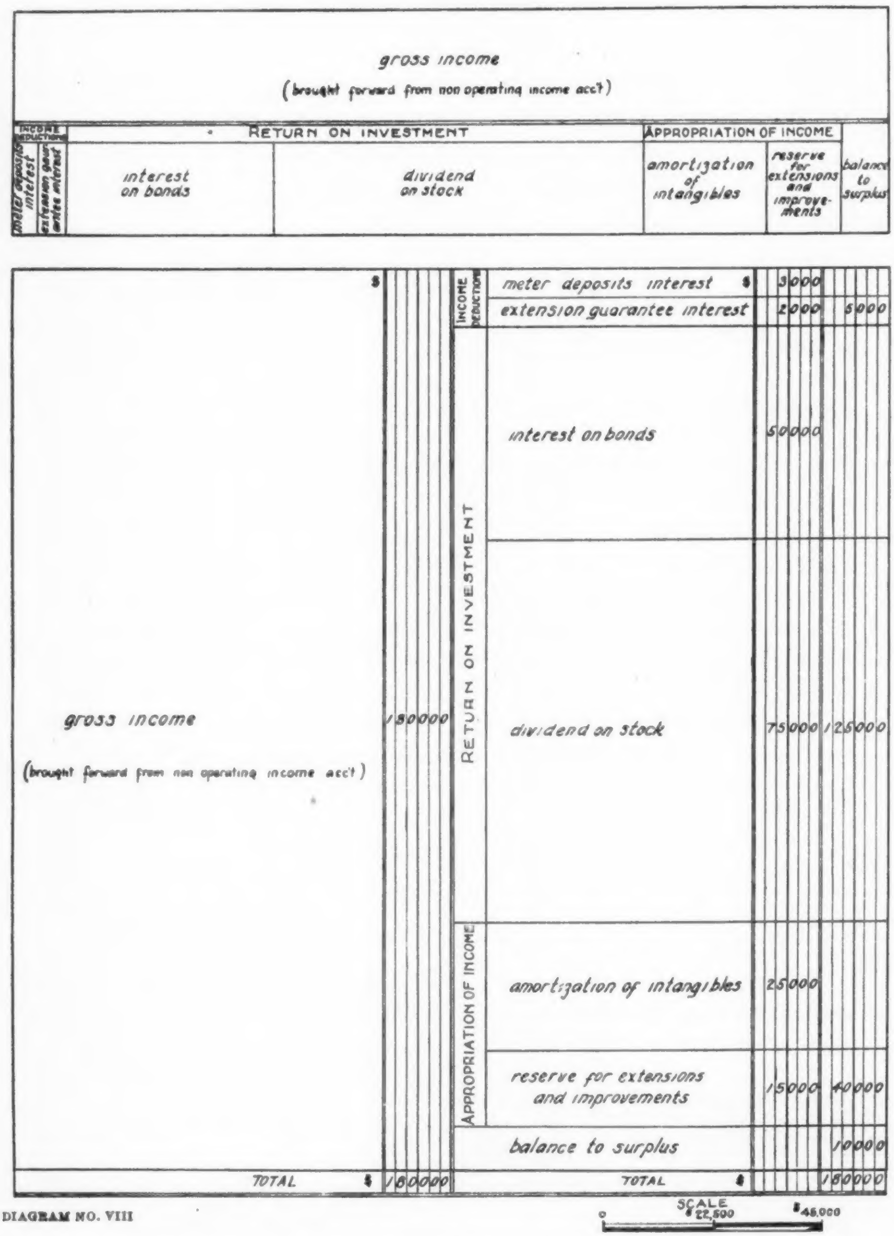


DIAGRAM NO. VIII

FIRE PROTECTION

The problem of estimating cost of fire protection is considered such an important one that special reference is made to it. Mr. Delos F. Wilcox, Deputy Commissioner, in making up the various tables shown in his report on the Queens County Water Company rate case, included those concerning fire protection. No doubt many of you have already read that report and are therefore more or less familiar with the following extracts from one of Mr. Wilcox's articles. Speaking of the Queens County case, he says:

In distributing the cost between domestic service and fire protection, the following method was pursued and the following results obtained:

We began by rejecting the obvious fallacy that the amount of water actually used for the putting out of fires in the course of a year is important. We regarded it as so unimportant that we made no allowance whatsoever for it in the final figures of cost.

We also rejected the fallacy, which seems sufficiently obvious after a little reflection, that the cost of fire protection can be measured by an annual hydrant rental at a fixed rate per hydrant. The hydrant is only the spigot out of which the fire-destroyi ng fluid flows. The conduits that convey the water, the pumps that drive it, the wells that furnish it, are substantially the same whether there are 500 hydrants or 1000. Clearly, if the cost of fire protection is apportioned to 500 hydrants on the basis of an annual rental per hydrant, when the number of hydrants is doubled the payment for fire protection will be greatly in excess of cost. The reverse would be true if the number of hydrants were reduced.

We also rejected the fallacy that the cost of fire protection can be fixed as a lump sum payable annually without change over a number of years; for if the number of hydrants is increased the company will get nothing for the additional investment and will rightly feel that every new hydrant ordered represents a dead loss to it, a sheer contribution to the expenses of government, a forced levy, so to speak.

We also rejected the contention, which in the absence of franchise or statutory provisions supporting it can hardly be dignified with the name theory, that a private water company is under obligation to serve the public organized as a city for nothing or for less than cost.

* * * * * * * *

We assumed that the company was organized primarily for the sale of water to private consumers for profits, and the city was entitled to get fire protection at its actual cost as an incidental or surplus service.

After putting a valuation upon the property used and useful in the water business, we were compelled to distribute it between domestic service and fire protection according to the theory adopted. Accordingly, we estimated the cost of a substitute plant fully adequate for domestic service, but without the reserve necessary to meet the fire hazard and without any of the equip-

ment designed exclusively for fire protection. The estimated cost we set up as the investment on the basis of reproduction cost new properly chargeable to domestic service. The difference between this investment and the cost of the company's plant as actually constructed and in use was treated as the surplus investment properly chargeable to fire protection. Of course, in arriving at the actual amount of the present investment, accrued depreciation was deducted.

On this basis we found that 23.2 per cent of the entire investment was attributable to fire protection. This percentage varied with the different classes of property. Of the value of the mains it was about 22 per cent; of pumping station buildings, 25.7 per cent; of water lands, wells and suction lines, 33 per cent; of pumping machinery and standpipes, 50 per cent; of hydrants, 100 per cent; of filters, meters, tools, office buildings and land, miscellaneous equipment and going value, no per cent.

* * * * * * * *

As the first element in the cost of fire protection, we charged up the fair return, 7 per cent on the 23.2 per cent of the investment regarded as surplus over what would have been necessary for domestic service. We also charged depreciation against this portion of the investment, the rate of depreciation having been figured out separately for each class of property. We then undertook to assign a proper portion of operating expenses and taxes to fire protection, and after a detailed analysis of the various classes of expenses we arrived at the conclusion that 15 per cent should be charged to fire protection. Putting the figures all together, we found that the company should receive from the city for fire protection and other hydrant uses about 21 per cent of its gross revenues. This was a little more than three times the percentage it had been receiving.

From the above it will seen that the annual cost of fire service is made up of three elements.

1. Return upon that portion of the investment necessary to provide fire protection.
2. Depreciation of property representing such investment.
3. Portion of operating expenses incidental to the rendering of fire service.

In order to determine the last element, it is essential that the accounts of the company furnish adequate classification of operating expenses, as is shown by the preceding Income Account. It is, however, not sufficient that the accounts be properly classified; it is at least equally important that they be assembled into an estimate such as hereinabove described. This is so apparent from the following diagram (No. IX) of Fire Protection Income Account, that further comment is unnecessary.

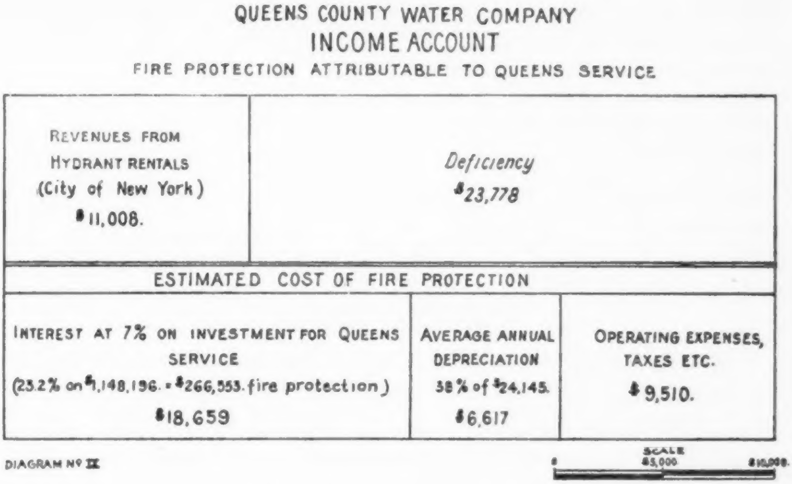


DIAGRAM Nº IX

The percentage of the various operating expenses attributable to fire protection is shown in the table below, the average being 15 per cent.

Class of Expenses	*Percentage Attributable to Fire Protection*
Salaries	6
Stationery and Office Supplies	0
Office Expenses (including telephone)	40
Operation of Pumping Station:	
Wages	10
Coal	0
Oil, Packing, Waste, Light	0
Minor Equipment	0
Rockaway Park Station	50
Reading Meters	0
Bottling	0
Stable and Garage Expense	20
Operation of Filters	0
Brooks and Streams	0
Maintenance of Mains	10
Maintenance of Boilers	25
Maintenance of Machinery (including pumps)	25
Maintenance of Buildings	25
Maintenance of Meters	0
Maintenance of Standpipes	50
Maintenance of Wells	33
Maintenance of Hydrants	100
Maintenance of Tools	0

Class of Expenses	*Percentage Attributable to Fire Protection*
Cleaning Pipes	26
Permits and Tapping	0
Inspection and Collection	0
Fire Insurance	38
Life Insurance	0
Miscellaneous Expenses	0
Legal Expenses	20
Taxes	26
Total ... Average	15

ACCOUNTING SYSTEMS

The wide scope of the subject which the author attempted to cover was not realized until the writing of this article was well under way. Originally, it was planned to introduce the accounts by classes and diagrams, and in addition thereto illustrate or describe a set of office and field records, including pumping station efficiency data, which would provide for the proper keeping of the accounts in conformity with the classifications. But the latter part of the plan had to be abandoned to avoid making the article too long, even though the discussion of some of the important items making up the Balance Sheet and Income Account have been slighted. In closing, however, the author will mention the fact that it has come to his attention that there are still a number of water works which do not accrue their income on a revenue and expenditure basis, but which take account of cash receipts and disbursements only. This, it is almost needless to remark, is a very dangerous practice, when it is considered that an ascertainment of the revenues and expenses applicable to a particular period, whether paid or not, is vital to the question of determination of proper rates.

As regards revenues, the chief difficulty seems to lie in the lack of proper charging records. To this end, the author would suggest the use of the following or similar form by companies billing once a year and rendering service on a flat rate basis. This record, Consumers' Register, can be modified according to the frequency of billing and the method of determining rates, whether based on frontage, fixtures, number of rooms or assessed valuation.

The two sheets shown fit in a loose leaf binder. The upper sheet is virtually a record of inspection and shows also the details of charges. It is more or less a permanent record, while the other sheet, being shorter, is an insert, which can be replaced or added

1

CONSUMERS' REGISTER (FLAT RATES)

FINANCIAL AUDIT CO. OF N.Y.

		Premises		Consumer			Characteristics				Charges								
												Extras					Others		
Line No.	Service No.	Street	No.	Name	Address	Particulars of Changes, etc.	Width of House	Stories in Height	Number of Families		Regular Rate	Bath	Water Closet	Sink	Family	Hose	Description	Amount	Line No.
1																			1
2																			2
3																			3
4																			4
5																			5
6																			6
7																			7

ACTUAL SIZE OF SHEET 21" x 17."

1

JANUARY 1st. 191 TO DECEMBER 31st. 191

					Payments														
Line No.	Total Yearly Charges	Unpaid Balance (Prior Years)	Additions	Rebates	January	February	March	April	May	June	July	August	September	October	November	December	Total Amount Paid	Balance Due at End of Current Year	Line No.
1					Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day			1
2																			2
3																			3
4																			4
5																			5
6																			6
7																			7

ACTUAL SIZE OF SHEET 10½" x 17"

to with the lapse of time. The latter shows record of payments, etc., arranged according to month. One side of this sheet will show payments for a year and another year's record will be shown on the back, after the leaf is turned to the left, to match the location shown on the left hand sheet.

A summation of the left hand sheet will give the total of the various classes of charges for a particular period. The right hand sheet will show the total amount of payments received within each month, total additions during year, total allowances, and total amount outstanding at the end of the year. The amount of consumers accounts receivable outstanding at the end of any particular month can also be readily ascertained therefrom.

As to the expenses, these can easily be ascertained by the installation of the unit system of vouchering, by means of which the charges against a particular account at the end of each month are ascertained by summing up vouchers contained in the file supporting the account. This does away with the voucher register and its accompanying multiplicity of columns. It also simplifies the cash book.

As regards capital expenditures, it is hardly necessary to add that the subject of proper accounting is most important, particularly in a public utility. In rate cases, the courts are looking with more and more favor upon the original cost method of valuation as against the cost of reproduction. The extensive use of the latter method in the past has not necessarily been due to a preference for that method on the part of the courts. In many cases its use can be attributed solely to the lack of proper original cost records, in the absence of which the courts have been obliged to accept the alternative. But so much attention has been directed to the need of proper original cost data that it would be unreasonable to expect the courts to continue indefinitely to accept the excuses advanced by corporations for not having the necessary information.

The author trusts that his efforts are substantially in compliance with the wishes of your association. He agrees with your genial secretary that it would take a fairly good size book to handle the subject adequately and that, if the whole subject is confined to a paper of limited space, it can only be covered in a general way. If this article is responsible for the discussion of some of the points involved, the object of the author will have been attained.

THE SELECTION, INSTALLATION AND TEST OF A 1,000,000 GALLON MOTOR DRIVEN CENTRIFUGAL PUMP

By S. R. Blakeman

INTRODUCTION

It may be of interest to mention first a few of the characteristics of the plant in which this pump test was made, as well as give a brief outline of the history of the plant and the conditions that necessitated the purchase of the above pumping unit.

The city of Dyersburg, Tennessee, owns and operates its own water and light plant, the origin of which dates back to 1903, at which time it was taken over from private ownership. Immediately after the purchase of this plant by the city, steps were taken to improve the plant and distribution system, so as to give good service at minimum cost; and at the present time it is safe to say that there are but few plants of its size that have as low water rate as the Dyersburg plant, everything being considered.

The plant is located on the banks of the Forked Deer River, a small stream, the turbidity of which runs very high throughout the year, and, of course, it was natural that the first supply should be taken from this stream; but after some experience with this supply, which was not at all satisfactory, it was decided to change to well water, thereby eliminating filtration and the extra expense connected therewith. However, upon the completion of several wells that were practically drilled in the river, it was at once seen that this water contained quite an amount of iron in solution, as ferrous carbonate, which would also require treatment and filtration. At present the total amount pumped is taken from deep wells, treated and filtered, excellent results being obtained.

The original design of the plant included two 10 x 16 x $10\frac{1}{4}$ x 10 inch Worthington Compound Pumps, one of these being used to lift water from the wells into the subsiding tanks for treatment, whence it flowed to the filters; the other pump being used to deliver water from the clear well directly into the mains against a pressure

of 80 pounds per square inch. Later, another steam pump was added to the plant having a capacity of 1,000,000 gallons per twenty-four hours. This pump was expected to act as an auxiliary for the other pumps.

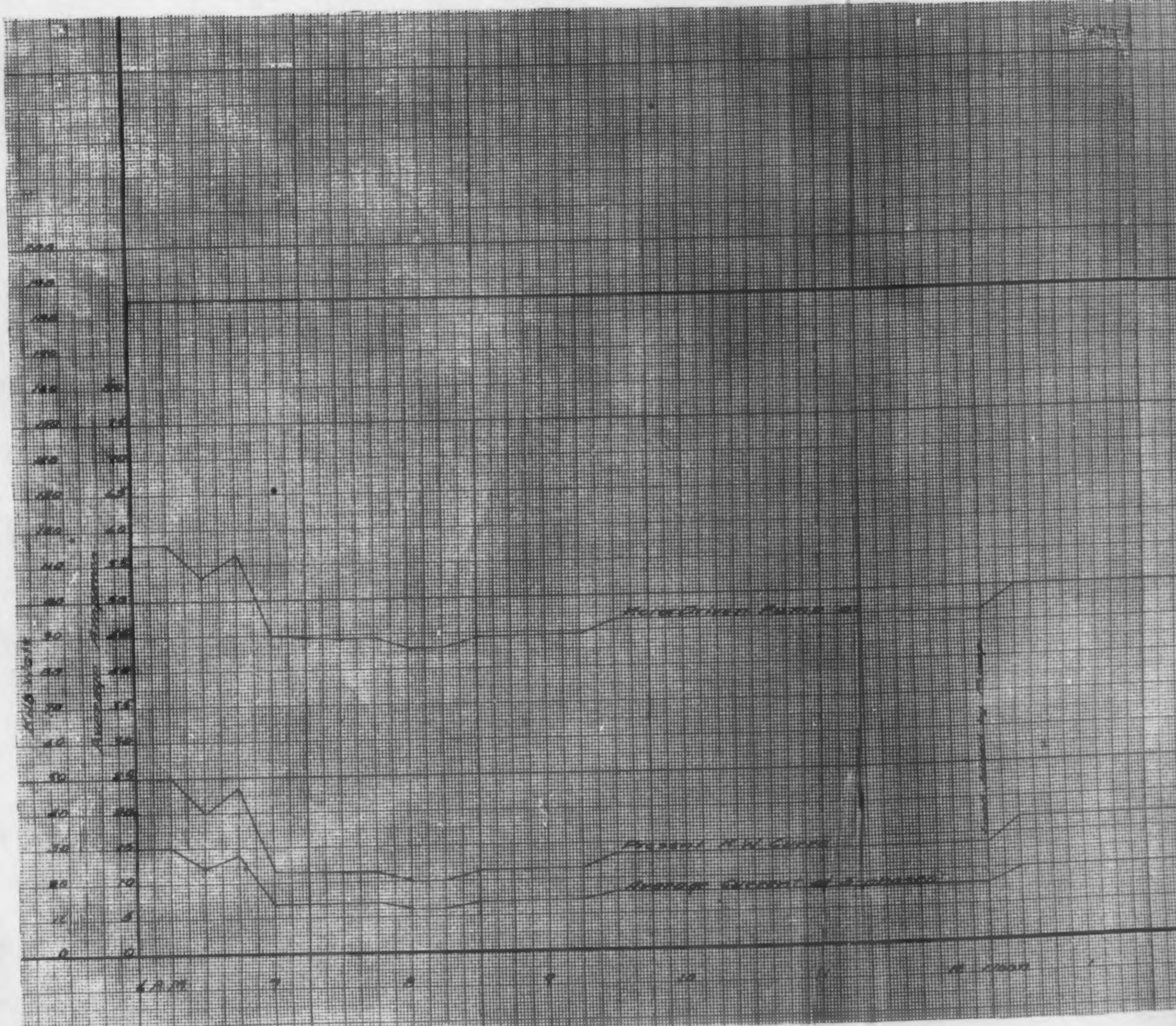
About the time the last mentioned steam pump was installed, two new engines and generators were installed having an aggregate capacity of 435 kilowatts. These replaced the original units, of much smaller size, the load on the station having exceeded their capacity. With the new equipment installed, the plant had to be operated for a large part of the time on very small load, below one half the rated capacity of the units.

The above engines being of the four valve, non-releasing Corliss type it was naturally to be expected that the steam consumption would be very high at light loads. The only relief for the above condition was additional load, which, of course, could only be obtained from a source outside of the plant and the installation of motor driven pumping units in the plant. With the addition of the average outside load, it was naturally to be expected that the load conditions would show quite a variation, the load curve rising to a peak when the lighting load was a maximum, during the early hours of the night, and gradually falling off and becoming a minimum during the later hours of the night. A typical load curve showing these conditions is shown on Plate I. Readings of the switchboard instruments were taken every fifteen minutes, to show small variations on this curve, the ordinates of these curves being in k.w. and the abcissa time, the power factor for each curve being assumed as the same.

The dotted curve shows variation of the load as taken on December 15, 1914, after a 6-inch motor driven volute pump had been installed, to replace one of the 750,000 gallon steam actuated pumps, this pump being designed to deliver 700 g.p.m. against a total head of 45 feet.

The load curve shown by solid line, Plate II, was taken from data obtained on December 24, 1915, after the motor driven turbine pump had been placed in operation. These curves show plainly the improved conditions of the load due principally to the addition of this pump.

Another feature, not to be overlooked, and which is shown on this curve, is how well the motor driven pump adapts itself to the load conditions of the plant. Since the installation of the turbine



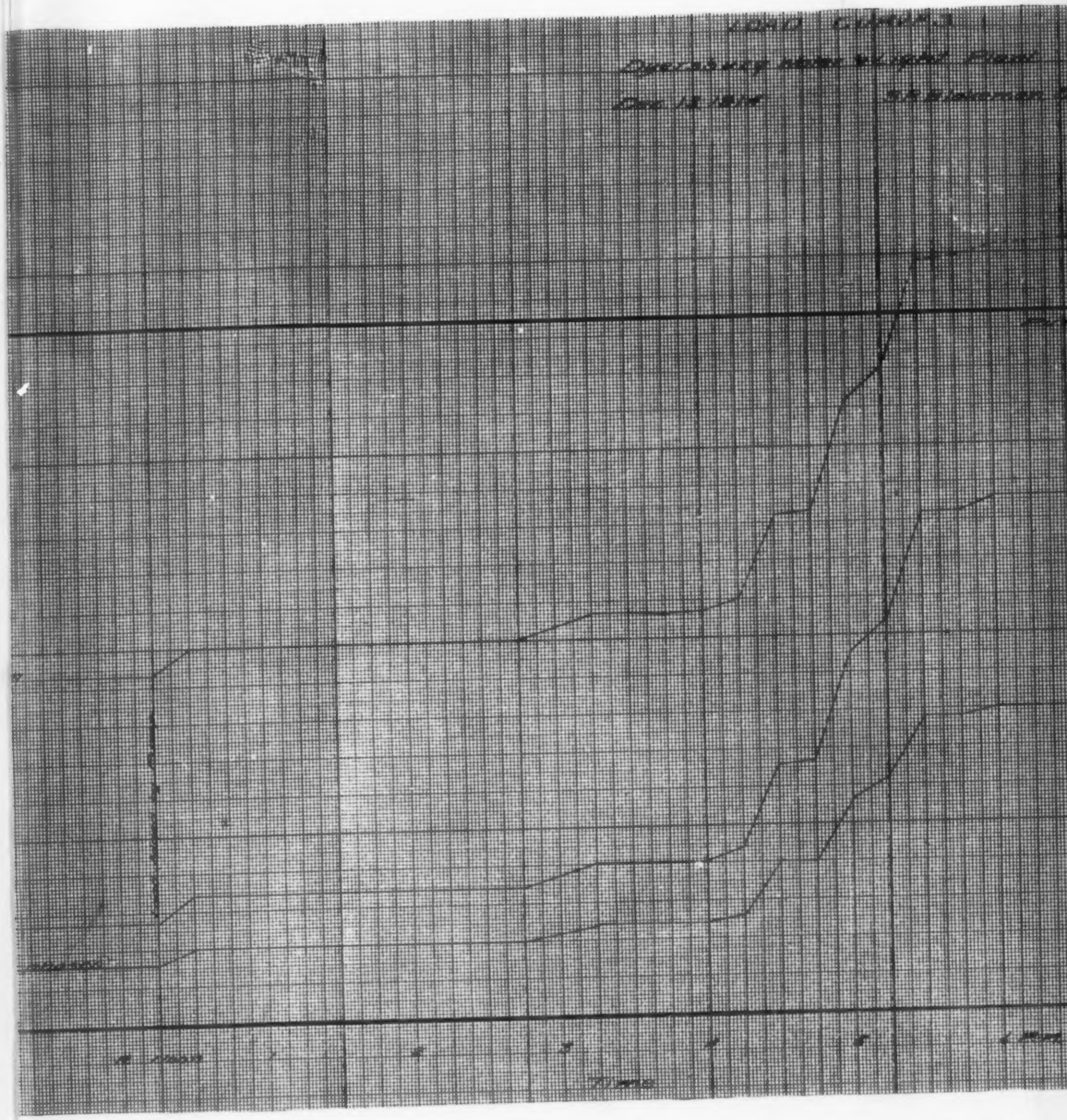
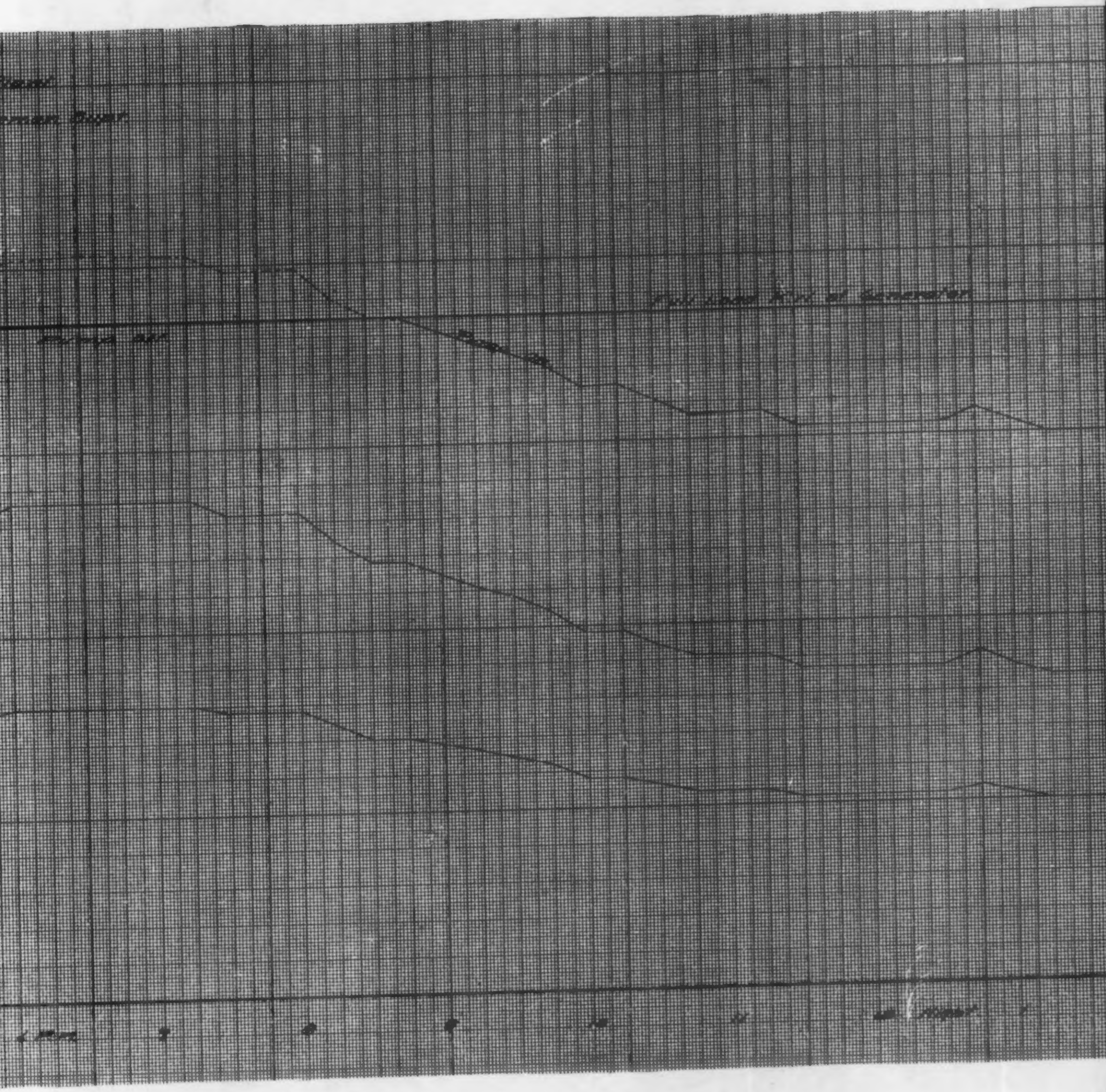


PLATE I



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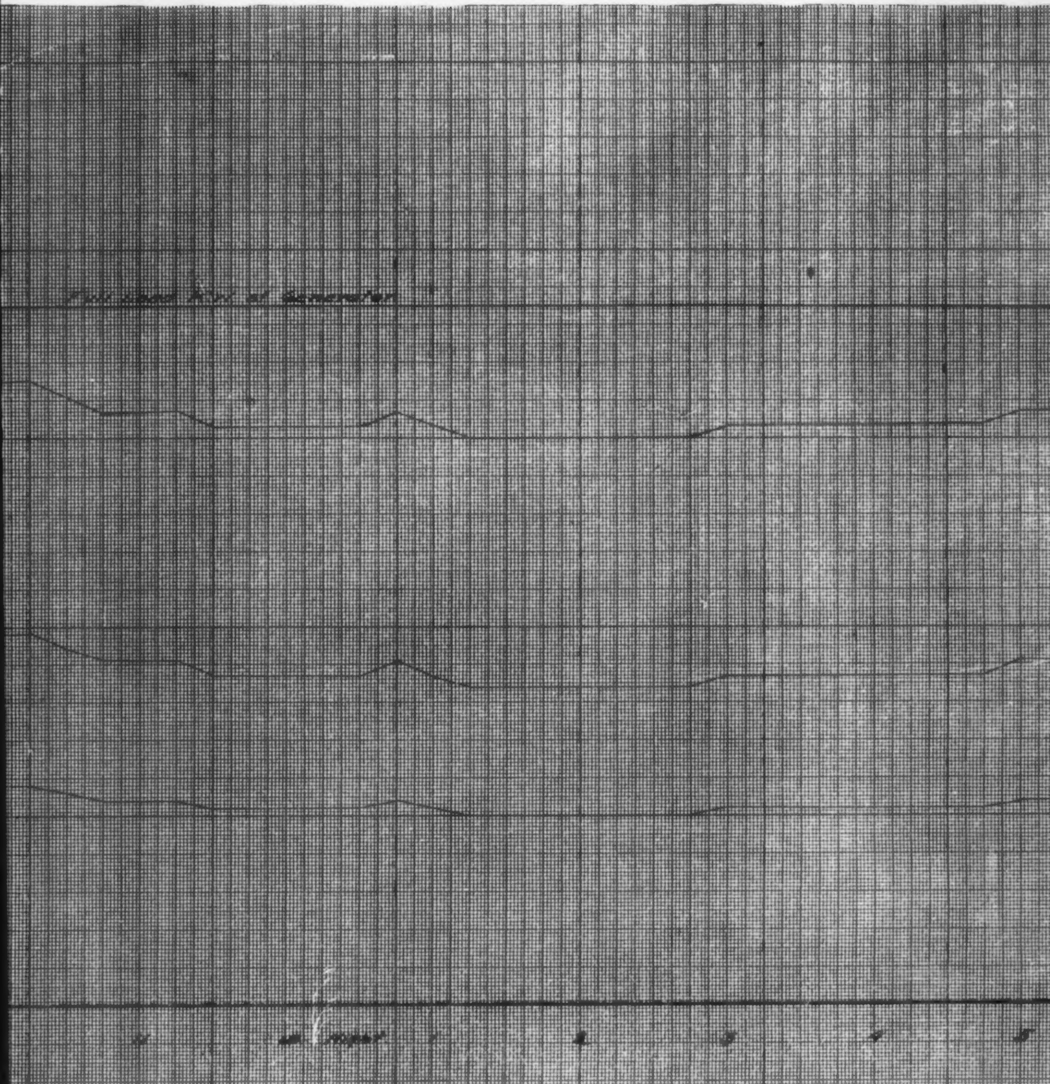
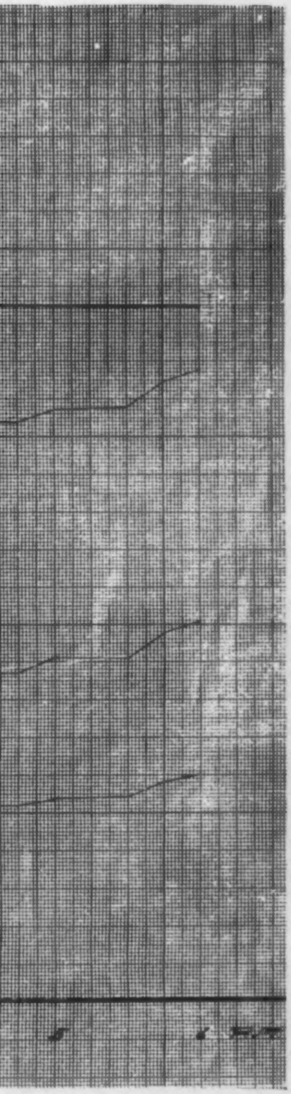
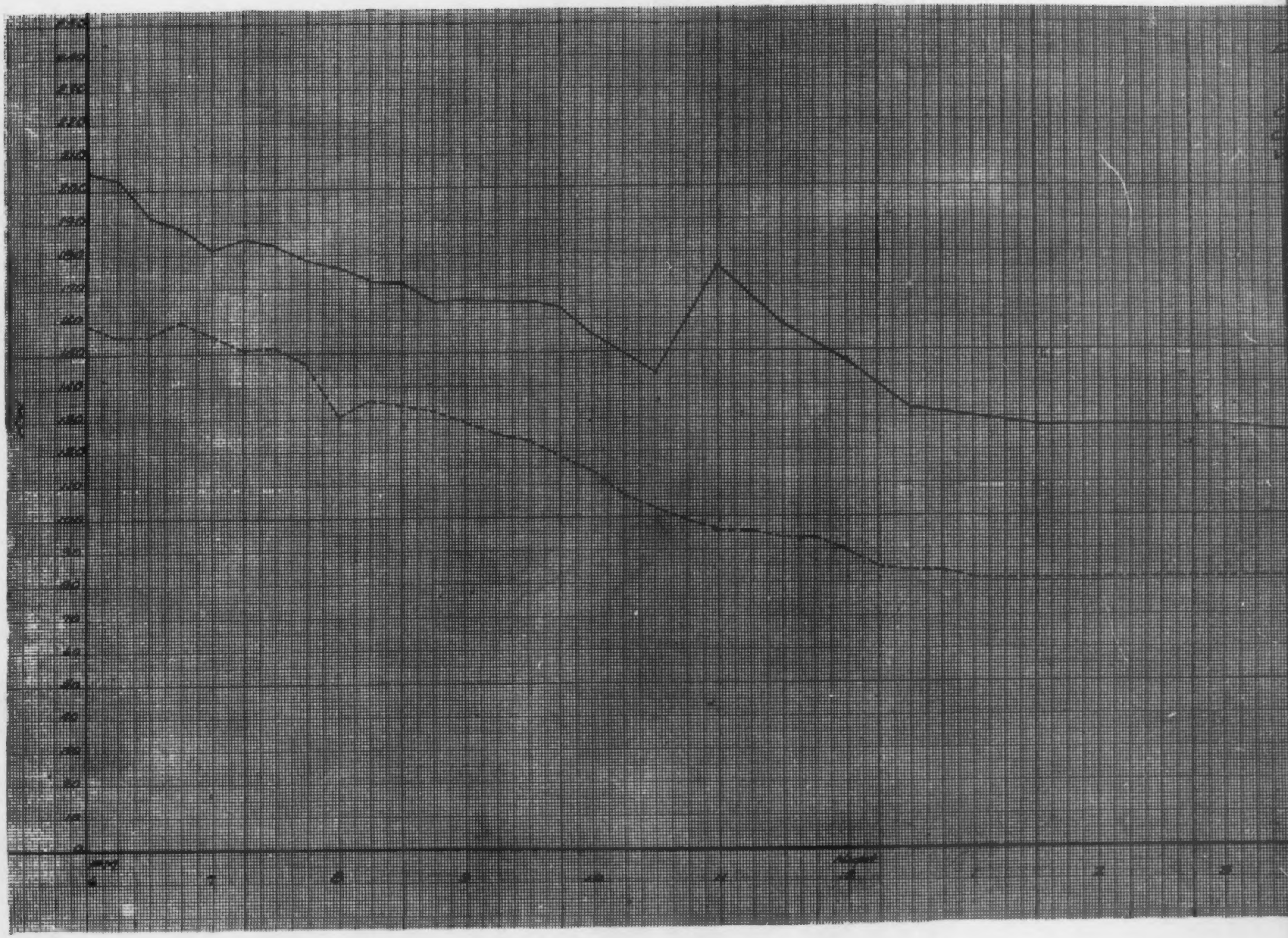
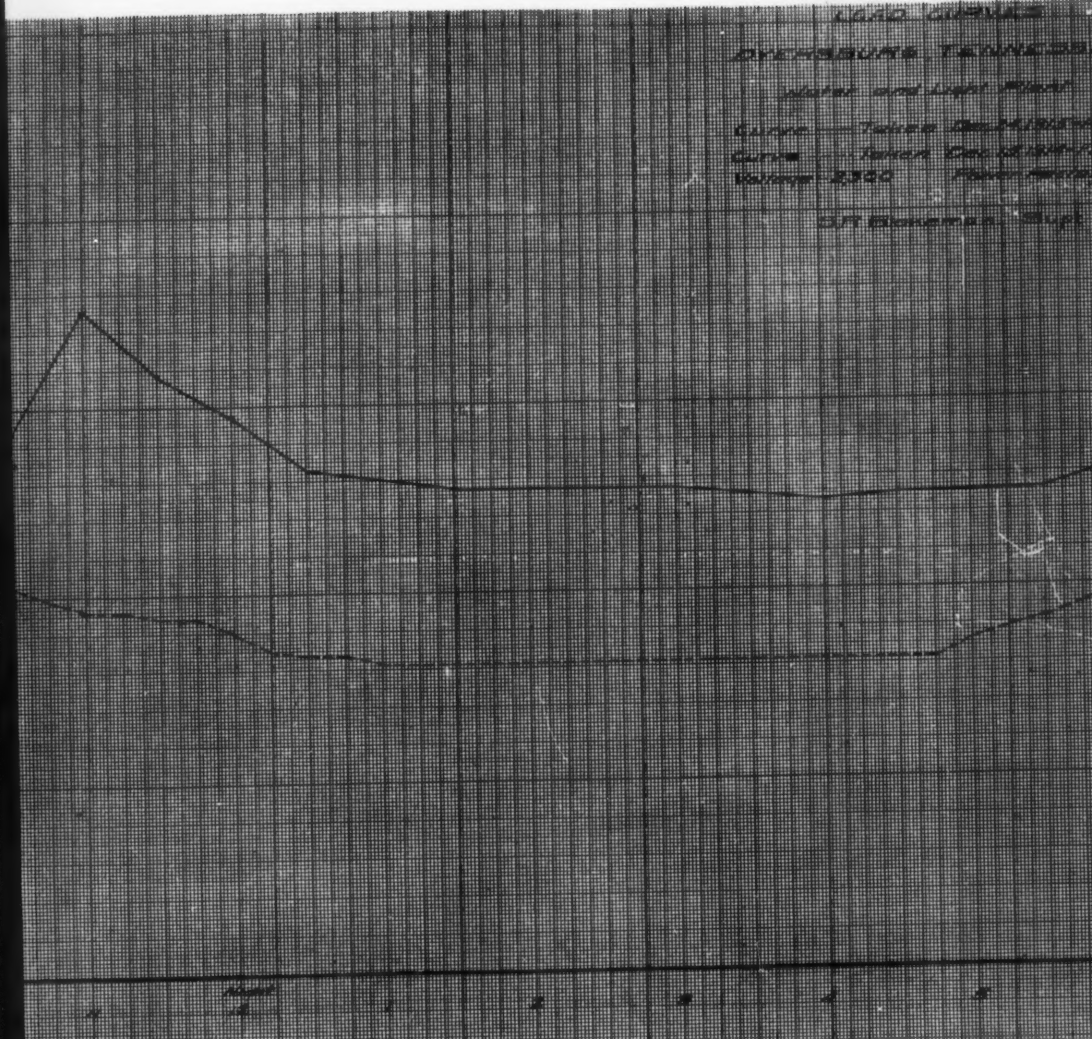

Full Load Run of Generator







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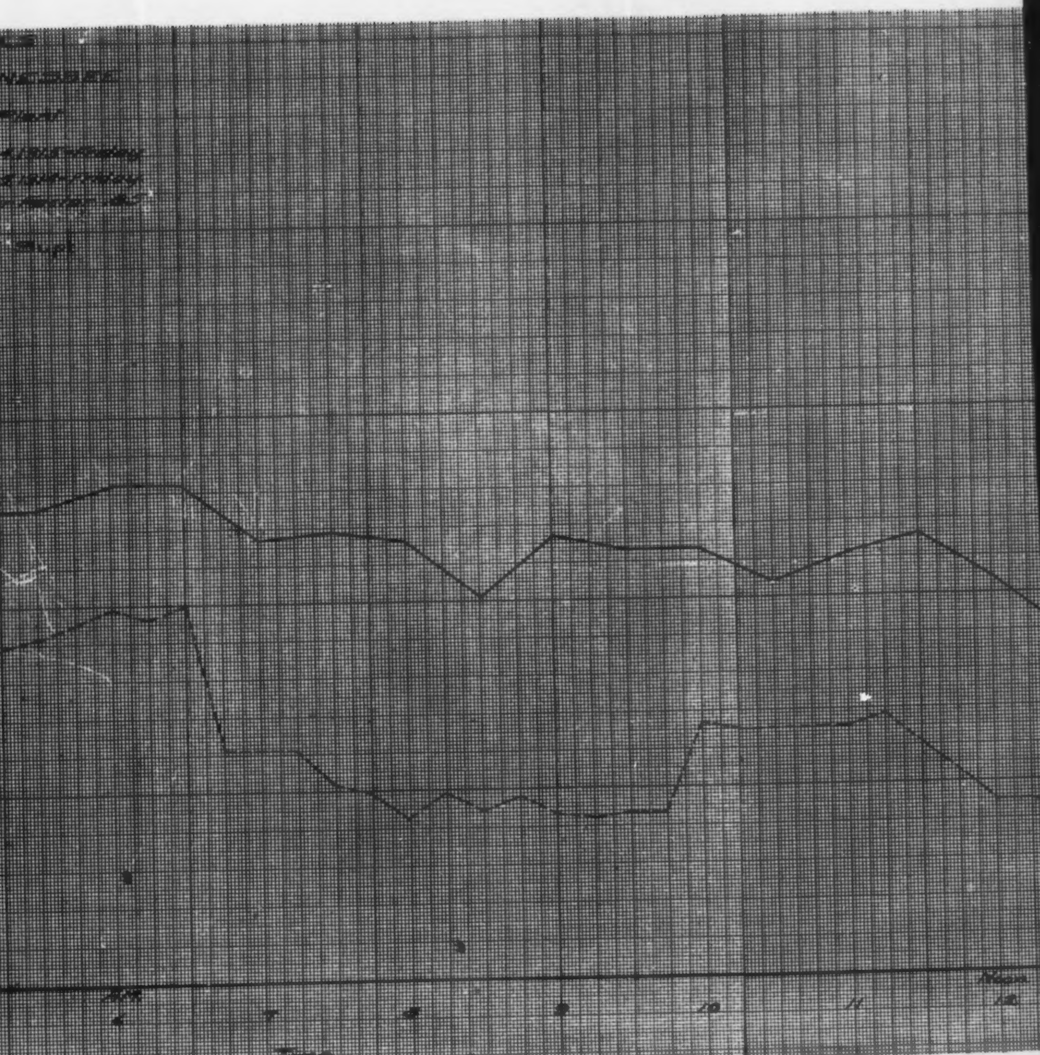
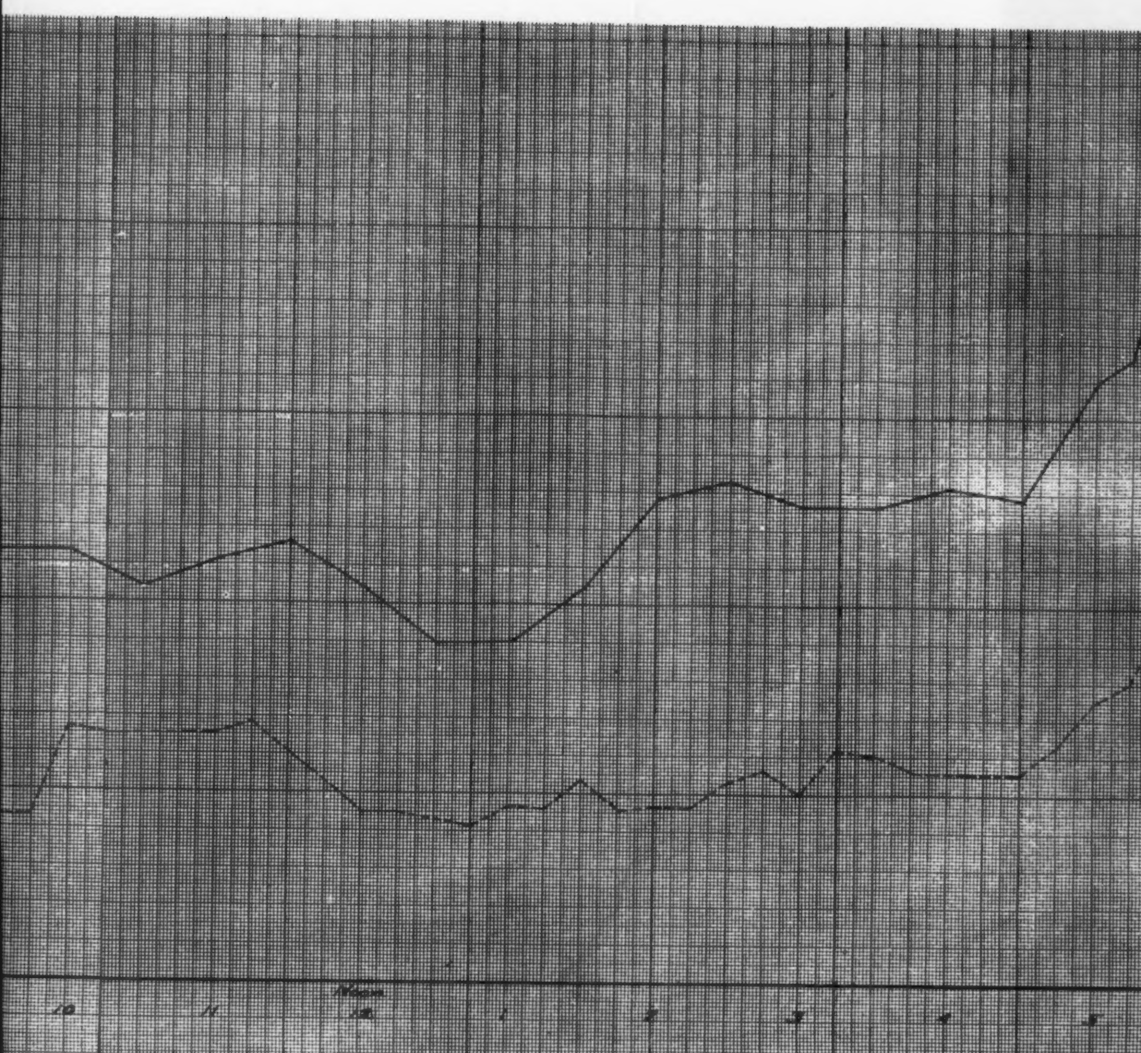


PLATE II



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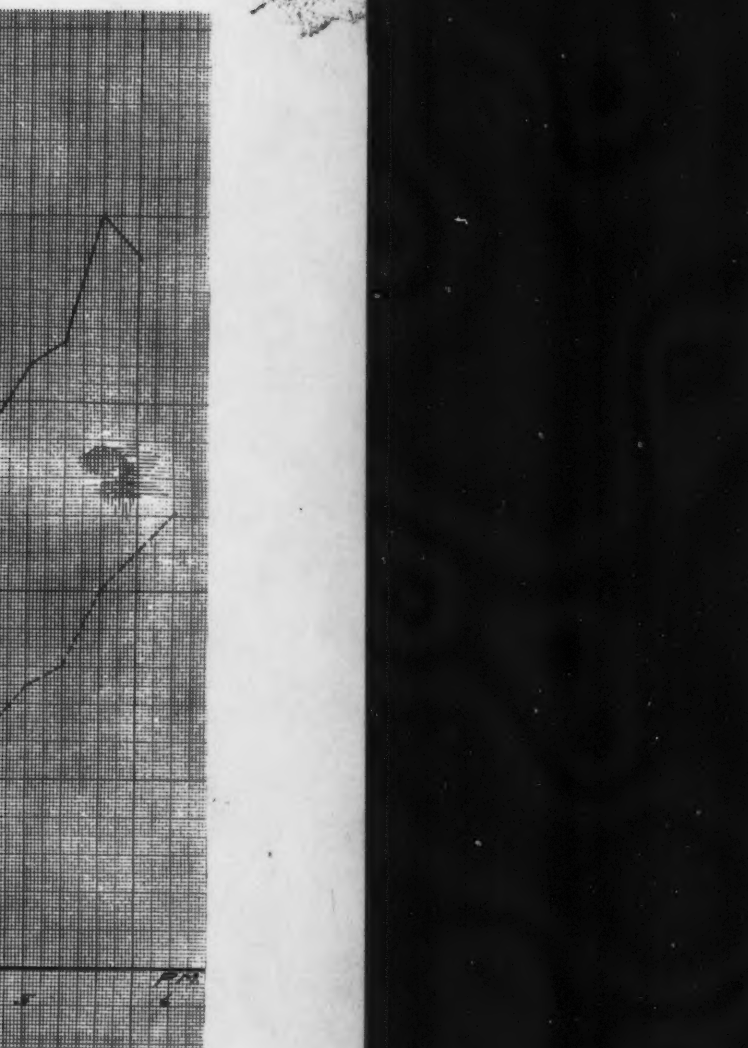


pump, a motor driven triplex boiler feed pump was installed, thereby eliminating the last steam actuated pump in the plant so far as regular operation is concerned.

Each of the above pumps is provided with a recording wattmeter. These meters are read every twenty-four hours, and from this information, the kilowatt hours consumed by each pump are computed. There is also a recording wattmeter on the switch board, recording the total output from the generator, the water meter, in the discharge from the turbine pump, giving us the total gallons pumped.

All this information, as well as a record of each ton of coal burned, is entered on the log sheet at the plant. From this, the pounds of coal required per k.w.h. generated, and per 1000 gallons pumped are figured, and properly entered.

A recording pressure gauge indicates the variation in pressure throughout the day. Plate III is an average gauge chart showing how uniformly the pressure is maintained throughout the day. It will be seen from this chart that the pump was shut down at 5.30 p.m., the pressure being 85 pounds per square inch. The electrical load, at this time, was beginning to reach a maximum. At 11.00 p.m. the curve shows the pump again running, the electrical load having reached nearly a minimum, the loss in pressure during this time amounting to only 5 pounds. A good feature of this installation is the fact that in the summer when the electrical load is minimum, the pumping load is maximum, and in the winter the reverse is true.

From these curves, it will be seen that the load factor of the station was very low. The guarantees on steam consumption for the engines when installed, were 32 pounds per i.h.p. hour, at one-fourth load and approximately twenty-four pounds, per i.h.p. hour when operating from one-half to full load. From this, assuming the steam consumptions are in the proportion as shown above, by adding sufficient load the steam consumption could be reduced to eight pounds per i.h.p. hour, and the efficiency of the generators increased from 5 to 10 per cent.

In the fall of 1914 an appraisal of the water works and electric light plant was made, from which the amount of fixed charges each carried per twenty-four hours was figured. Next, a series of tests were made, extending over a period of more than a week, during which twice the amount of fuel, labor, oil, etc., required to pump 1000 gallons of water was determined; in this data, were also included the kilowatt hours supplied the volute pump, and also the lime used

in the filtration department. After working out the above tests, the average cost of pumping 1000 gallons, including capital charges and depreciation on machinery, was found to be \$0.064. The average cost of generating a k.w.h., including capital charges and depreciation, was found to be \$0.028. The latter charge had to be

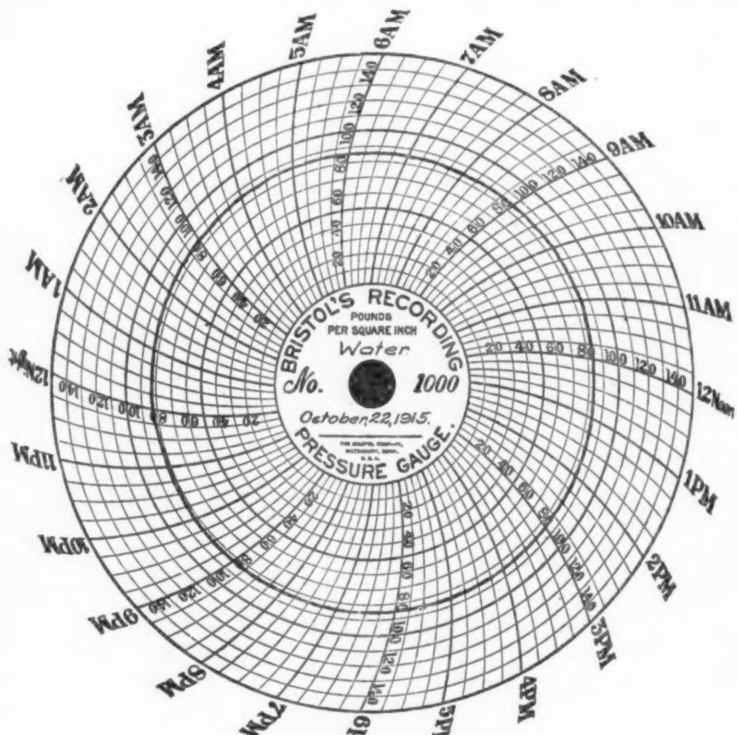


Plate III

determined in order that the cost of operating the motor driven volute could be found.

With all of the above information available, it was at once seen that by the addition of a motor driven pump the economy of the plant could be materially increased. However, before making any final decision it was thought wise to weigh all matters well and see how a triple expansion pumping engine would compare with the motor driven turbine pump; theoretically it was shown that the

motor driven pump would effect a saving over the pump then in operation of 511 tons of coal per year, which at $1.75 per ton delivered in the boiler room would amount to an annual saving of $894.25.

While the above showed the theoretical saving that would be effected by this installation, accepting the guarantees on the engines and generators as correct, it does not show the total amount saved, such as oil, maintenance, packing, etc., over the steam actuated pump, nor does it give a fair comparison of the two units.

The following formulae will bring out the above more plainly.

$$C = \frac{A \times W \times H \times P}{D} + F\,(I + D) + L + M$$

for the triple expansion pumping engine and

$$C = \frac{A \times W \times H \times K}{2{,}655{,}000 \times \text{overall efficiency of pump and motor}} + F\,(L + d) + L + M$$

for the motor driven pump.

In the above formulae:

C = Total cost of pumping per year.
A = Gallons pumped per year.
W = Weight of a gallon of water.
P = Cost of steam per thousand pounds.
H = Average total head pumped against.
D = Average duty in foot pounds per thousand pounds steam.
F = Total investment.
i = Rate of interest on investment.
d = Rate of depreciation.
M = Yearly cost of miscellaneous expenses of operation.
L = Yearly cost of operating labor.
K = Cost of power per k.w.h.

Triple expansion pumping engine	*Motor driven turbine pump*
A = 219,000,000 gallons	A = 219,000,000 gallons
W = 8.33 pounds	W = 8.33 pounds
H = 175 feet	H = 175 feet
P = .175	K = .02
D = 78,000,000	D = 2,655,000 foot pounds
F = $5780	F = $1500

Triple expansion pumping engine

i = 5 per cent
d = 5 per cent
L = \$1200
M = \$200

Motor driven turbine pump

i = 5 per cent
d = 5 per cent
L = \$1000
M = \$50

Then the formulae:

$$C = \frac{A \times W \times H \times P}{D} + F\,(i + d) + L + M,$$

gives for the steam pump,

$$C = \frac{219{,}000{,}000 \times 8.33 \times 175\ .175}{78{,}000{,}000} + \$5780\,(5\% + 5\%) + \$1200 + \$200$$

or

$$C = \$2694.25$$

For the motor driven turbine pump, the formula was used:

$$C = \frac{A \times W \times H \times K}{2{,}655{,}000 \times \text{overall efficiency of pump and motor}} + F\,(i + d) + L + M.$$

Then, by substitution,

$$C = \frac{219{,}000{,}000 \times 8.33 \times 175 \times .02}{2{,}655{,}000 \times 0.61} + \$1500\,(5\% \text{ and } 5\%) + \$1000 + \$50$$

or

$$C = \$1203.94$$

From this it will at once be seen that there would be an annual saving in the cost of pumping by the motor driven turbine pump over the triple expansion pumping engine of \$1490.31; proving that the motor driven turbine pump, everything being considered, would effect the greater saving.

The following specifications were adopted before asking for bids.

Specifications for Motor Driven Pump for Dyersburg Water and Light Department, Dyersburg, Tennessee

Capacity 700 g.p.m. Head 230 feet

1. The casing must be so arranged that it can be opened and the impeller and all working parts removed without breaking the suction and discharge connections to the pump and without disassembling the working parts themselves or disturbing the main pump casing or bed plate.

2. When this pump casing is opened all passages must be accessible.

3. The parts shall be of such material and so arranged that corrosion caused from long use will not render dissembling difficult.

4. The pump casing shall be so designed and built that it will be amply strong to withstand the pressure the pump was designed for, and which at maximum head the pump is capable of enveloping.

5. All rotating parts that will come in contact with water must be constructed of bronze, to prevent corrosion.

6. There shall be ample room for packing the stuffing boxes and the shaft must be protected from wear by the use of a bronze sleeve.

7. The builder must furnish with his proposition a blue print, showing the characteristics of the pump that he proposes to furnish, this showing the efficiencies, head capacity and brake horse power characteristics that he will guarantee when the pump is tested on the foundation at the station. After the pump has been built, it must be tested in the builder's shop and a certified copy of this test must be furnished, including the characteristics and the actual data obtained from the test.

8. The bearings must be so constructed that they may be removed without disturbing any part of the pump except the bearing caps.

9. The shaft must be rigid and perfectly balanced and protected from direct contact with the water.

10. All parts shall be made on an interchangeable basis so that they will fit properly and may be quickly obtained.

11. The pump must be equipped with a flexible coupling. The motor to be shipped to the company manufacturing the pump and mounted at the expense of the pump maker.

12. The price of the pump to be f.o.b. cars at our station.

13. With the pump proposition must be furnished the following: Size of suction, size of discharge, revolutions per minute, number of stages, weight of pump, delivery in days after receipt of order and terms of sale.

14. Foundation plans must be furnished upon receipt of order.

These specifications were sent to fifteen manufacturers of centrifugal pumps.

ANALYSIS OF BIDS

As soon as bids were received, they were tabulated as shown on the attached "Analysis Sheet," Plate IV. From the characteristic curve sheet, the efficiency, head and brake horse power were determined for discharges of 100, 200, 300, 400, 500, 600, 700 and 800 gallons per minute, the values being entered as shown on the table.

It may be seen from the load curve sheet that the load shows considerable variation in twenty-four hours, and, as the duty of this unit is to help build up the offpeak load, it will be seen that for certain periods of the day the discharge would have to be throttled to reduce the load on the engine or the pump be shut down, especially when the small generator was in operation, to keep the standpipe practically full at all times. Therefore, it was important that the average efficiency of the pump from 200 to 700 g.p.m. be as high

as possible. A column on the analysis sheet is so tabulated. In other words, it was desired to secure a pump that would show a flat efficiency curve. Some very interesting examples of this are shown on the analysis sheet, for instance, one pump shows a maximum efficiency of 69 per cent at 700 g.p.m. and only 14 per cent efficiency at 100 g.p.m. and an average efficiency of only 47.7 per cent. It will be seen that pump "F" shows an extra high efficiency, but failed to comply with the specifications. Several of the pumps listed did not conform with the specifications, but they were listed to show their other features.

The cost of foundation and the installation charges were estimated to be the same for each pump. It can readily be seen why pump "A" was bought, also motor "P."

In order to reduce transmission losses and transformer expense to a minimum it was decided to make use of a 2300 volt, three phase motor. Had a 220 volt motor been selected, the initial cost would have been greatly increased. A comparative cost of the two is:

Price of 2300 volt motor with starting box......		$439.47
Price of 220 volt motor with starting box.......	$627.26	
Price of 3-25 k.w. transformers.................	548.88	
Labor installing above..........................	20.00	
Total...	$1,196.14	$439.47

This shows a saving in initial cost of $756.67 in favor of the 2300 volt motor. In addition to the above, taking into consideration the three transformers, there would be effected an annual saving in interest on the investment, depreciation and transmission losses of approximately $188.28. It would then be evident that the high voltage installation would be the most economical.

On the analysis sheet, there will be seen an analysis of three motors, showing the efficiencies and power factors for $\frac{1}{2}$, $\frac{3}{4}$, full load and 25 per cent overload. Motor "P" was selected, due to the fact that it was thought better adapted for the work than either of the others. Motors "S" and "P" show practically the same efficiency and power factor for different loads.

The progress of the centrifugal pump has been held back to a certain extent, due to the fact that many mistakes are made in their selection, and more care is required in this type of pump than any other, especially regarding the subject of head. In the installa-

PLAT

Analysis of a proposed motor driven centrifugal pump installation for Dyersburg Water and

MAKE OF PUMP	MAKE OF MOTOR	SUCTION HEAD	DISCHARGE HEAD	TOTAL HEAD	G. P. M.	SIZE OF SUCTION	SIZE OF DISCHARGE	R. P. M.	TYPE OF CASING	BRAKE HORSE POWER	MOTOR HORSE POWER	PER CENT OF MOTOR H. P. DEVELOPED	COUPLING	IMPELLER	STAGES	WT. PUMP AND MOTOR	F. O. B. DYERSBURG	DELIVERY—DAYS	EFFICIENCY				AVERAGE EFFICIENCY 200 TO 700 G. P. M.	PRICE OF MOTOR, PUMP AND STARTER	COST OF FOUNDATION
																			Motor	Pump	Transmission	Overall			
"A"	"P"	10′	220′	230′	700	6″	5″	1,800	Hor. split	64.5	75	86	Flex	Bronze	2		Yes	60	0.91	0.68	0.98	0.60	58.0	$952.86	$20
"B"	"P"	10′	220′	230′	700	5″	5″	1,800	Hor. split	62.6	75	84	Flex	Bronze	2		Yes	120	0.91	0.65	0.98	0.58	47.5	$1,180.00	20
"C"	"P"	10′	220′	230′	700	5″	5″	1,800	Hor. split	55.5	75	74	Flex	Bronze	2		Yes	30	0.91	0.64	0.98	0.57	56.0	977.00	20
"D"	"R"	10′	220′	230′	700	6″	6″	1,800	Hor. split	63.0	75	84	Flex	Bronze	2		No	75	0.90	0.65	0.98	0.56	53.5	1,300.00	20
"E"	"S"	10′	220′	230′	700	6″	5″	1,800	Hor. split	66.0	75	88	Flex	Bronze	2		Yes	30	0.90	0.66	0.98	0.58	49.0	975.00	20
"F"	"S"	10′	220′	230′	700	6″	6″	1,800	Vert. split	53.9	75	72	Flex	Bronze	4	6,000 lbs.	No	40	90.5	0.75	0.98	0.67	62.5	1,035.00	20
"G"	"P"	10′	220′	230′	700	6″	6″	1,800	Hor. split	62.0	75	83	Flex	Bronze	2		Yes	45	0.91	0.65	0.98	0.58		969.68	20
"H"	"P"	10′	220′	230′	700	8″	6″	1,800	Vert. split	59.0	75	78	Flex	Bronze	2	6,300 lbs.	Yes	60	0.91	68.5	0.98	0.61	47.7	1,039.00	20
"I"	"Q"	10′	220′	230′	700	5″	5″	1,800	Hor. split	68.0	75	90	Flex	Bronze	2	4,000 lbs.	Yes	120	0.90	0.60	0.98	0.53	46.0	1,156.85	20
"J"	"S"	10′	220′	230′	700	6″	5″	1,800	Hor. split	61.5	75	81	Flex	Bronze	2		No	21	90.5	0.66	0.98	0.58	52.0	1,186.40	20
"K"	"S"	10′	220′	230′	700	7″	5″	1,800	Hor. split	62.0	75	83	Flex	Bronze	2		No	120	90.5	0.65	0.98	0.58	47.5	1,226.20	2
"L"	"S"	10′	220	230′	700	6″	6″	1,800	Hor. split	60.0	75	80	Flex	Bronze	2		Yes	60	90.5	0.68	0.98	0.60	46.5	1,330.00	2
"M"	"S"	10′	220′	230′	700	6″	6″	1,800	Hor. split	64.5	75	86	Flex	Bronze	2		Yes		90.5	0.63	0.98	0.56		1,022.00	2
"N"	"P"	10′	220′	230′	700	5″	5″	1,800	Hor. split	63.5	75	85	Flex	Bronze	2	5,390 lbs.	No		0.91	0.64	0.98	0.57	51.0	1,244.00	2
"O"	"S"	10′	220′	230′	700	6″	6″	1,800	Hor. split	65.6	75	87	Flex	Bronze	2	5,400 lbs.	Yes	240	90.5	0.62	0.98	0.54	49.0	1,000.00	[illegible]

PLATE IV

ntrifugal pump installation for Dyersburg Water and Light Plant, Dyersburg, Tennessee,

STAGES	WT. PUMP AND MOTOR	F. O. B. DYERSBURG	DELIVERY—DAYS	EFFICIENCY				AVERAGE EFFICIENCY 200 TO 700 G. P. M.	PRICE OF MOTOR, PUMP AND STARTER	COST OF FOUNDATION	INSTALLATION	TOTAL COST	100 G. P. M.			200 G. P. M		
				Motor	Pump	Transmission	Overall						Efficiency	Head	B. H. P.	Efficiency	Head	B. H. P.
2		Yes	60	0.91	0.68	0.98	0.60	58.0	$952.86	$20.00	$527.14	$1,500.00	0.20	300	40	0.36	305	4
2		Yes	120	0.91	0.65	0.98	0.58	47.5	$1,180.00	20.00	527.14	1,727.14	0.15	258	33	0.30	258	4
2		Yes	30	0.91	0.64	0.98	0.57	56.0	977.00	20.00	527.14	1,524.14	0.26			0.48		
2		No	75	0.90	0.65	0.98	0.56	53.5	1,300.00	20.00	527.14	1,827.14	0.18	280	36	0.33	277	4
2		Yes	30	0.90	0.66	0.98	0.58	49.0	975.00	20.00	527.14	1,522.14	0.18	294	38	0.32	290	4
4	6,000 lbs.	No	40	90.5	0.75	0.98	0.67	62.5	1,035.00	20.00	527.14	1,582.14	0.30	292	216	0.52	292	2
2		Yes	45	0.91	0.65	0.98	0.58		969.68	20.00	527.14	1.516.82	0.26	285	27	0.39	285	3
2	6,300 lbs.	Yes	60	0.91	68.5	0.98	0.61	47.7	1,039.00	20.00	527.14	1,586.14	0.14	275	46	0.28	275	4
2	4,000 lbs.	Yes	120	0.90	0.60	0.98	0.53	46.0	1,156.85	20.00	527.14	1,703.99	0.18	272	36	0.32	270	4
2		No	21	90.5	0.66	0.98	0.58	52.0	1,186.40	20.00	527.14	1,733.54	0.23	262	30	0.38	264	3
2		No	120	90.5	0.65	0.98	0.58	47.5	1,226.20	20.00	527.14	1,773.34	0.21	318	40	0.36	326	4
2		Yes	60	90.5	0.63	0.98	0.60	46.5	1,330.00	20.00	527.14	1,877.14	0.11	292	25	0.23	284	3
2		Yes		90.5	0.63	0.98	0.56		1,022.00	20.00	527.14	1,569.14	0.18			0.30		
2	5,390 lbs.	No		0.91	0.64	0.98	0.57	51.0	1,244.00	20.00	527.14	1,791.14	0.16	264	20	0.38	264	3
2	5,400 lbs.	Yes	240	90.5	0.62	0.98	0.54	49.0	1,000.00	20.00	527.14	1,547.14	0.25	280	32	0.37	277	4

...nnessee, February 20, 1915. S. R. Blakeman, superintendent

CHARACTERISTIC OF PUMP VARIABLE DISCHARGES

200 G. P. M.			300 G. P. M.			400 G. P. M.			500 G. P. M.			600 G. P. M.			700 G. P. M.			800 G. P. M.		
Efficiency	Head	B. H. P.	Efficiency	Head	B. H. P.	Efficiency	Head	B. H. P.	Efficiency	Head	B. H. P.	Efficiency	Head	B. H. P.	Efficiency	Head	B. H. P.	Efficiency	Head	B. H. P.
.36	305	45	0.48	302	50	0.58	296	55	0.65	290	60	0.68	272	62	0.68	250	65	0.65	215	70
.30	258	40	0.44	258	45	0.52	252	49	0.58	248	53	0.64	240	58	0.64	230	63	0.50	152	61
.48			0.59			0.63			0.66			0.67			0.60					
.33	277	42	0.45	275	46	0.54	270	51	0.60	262	55	0.64	250	59	0.65	230	63	0.63	205	65
32	290	44	0.44	288	50	0.50	280	54	0.56	273	60	0.61	255	62	0.64	240	66	0.66	220	68
52	292	28	0.62	289	35	0.70	287	43	0.74	276	46	0.78	260	51	0.78	230	52	0.74	191	52
39	285	34	0.50	280	42	0.58	276	48	0.61	264	52	0.65	248	58	0.65	230	62	0.63	207	65
28	275	48	0.39	275	50	0.49	270	53	0.58	262	55	0.64	252	57	0.69	230	59	0.69	218	61
32	270	42	0.42	267	48	0.50	260	54	0.55	255	58	0.58	245	64	0.60	230	68	0.59	210	72
38	264	36	0.48	262	42	0.56	260	46	0.61	252	52	0.64	245	56	0.66	230	62	0.65	212	66
36	326	45	0.47	312	50	0.56	295	53	0.61	275	57	0.63	251	59	0.65	230	62	0.63	200	64
23	284	30	0.34	276	40	0.45	268	45	0.55	260	50	0.62	248	55	0.67	236	60	0.67	220	65
.30			0.40			0.46			0.54			0.59			0.64			0.66		
.38	264	34	0.49	262	40	0.56	260	44	0.61	256	54	0.63	246	60	0.64	230	63	0.60	180	58
.37	277	40	0.44	275	47	0.50	262	54	0.54	255	60	0.58	248	65	0.61	237	70	0.63	225	73

MOTOR CHARACTERISTIC

	"R"		"S"		"P"	
Load	Efficiency	Pf.	Efficiency	Pf.	Efficiency	Pf.
1/4						
2/4	88.0	81.0	88	86.0	89.0	80
3/4	89.5	88.0	91	91.5	91.0	88
4/4	90.0	91.0	91	93.0	91.0	91
1 1/4	90.0	92.5	90	93.0	90.5	92

Voltage of Motor—2,300

Phase 3

Cycles 60

tion in question care was exerted to see that the pump selected would fit the work imposed upon it. A very careful survey of all conditions was made, such as measuring the number of feet of main, the size and number of specials in the suction and discharge lines, including a survey with an engineer's level, to determine the exact elevations of all points required, no gauge records being relied upon.

The result of this survey follows:

Head in discharge line

	Feet
Friction losses in 3380 feet of 10 inch C. I. pipe	14.26
Friction losses in 1220 feet of 12 inch C. I. pipe	2.08
Friction losses in 6–10 inch of C. I. ells	0.96
Friction losses in 10 inch suction line	1.27
Difference in elevation, center line of pump and low stage of river	18.30
Difference in elevation, center line of pump and hose of standpipe	132.70
Height of standpipe	50.00
Total head	219.57

To this was added 10.43 feet, an amount great enough to give all houses surrounding the standpipe a reasonable domestic pressure. In order to obtain a maximum efficiency under operating condition, a line had to be drawn, for had a pump been selected designed to furnish fire service at points located on high elevations, at the rated discharge of the pump, it would necessarily have meant that it would have to operate at a very low efficiency when pumping against ordinary pressure.

This condition had to be met and at the same time the pump had to be able to render maximum efficiency. In order to make use of the volute pump at times of fire it was proposed to pipe the two pumps so that they could be cut in series. Both being 700 gallon pumps and having similar characteristics made this condition practical. It will at once be seen that a plan of this kind would enable us to run efficiently both pumps practically all of the time and to also have two pumps available that, when run in series, were capable of giving excellent fire pressure.

INSTALLATION

Having decided upon the motor and pump, the next step was to make plans for locating and installing them. The location that presented itself that would answer the purpose without building or extending the present plant was a small room 13 x 16 feet. By locating the pump here, the suction lift was reduced to a minimum. This installation is interesting in view of the fact that no other type of pump having the same capacity could possibly have been so located. Due to the available space left in this room, and also the fact that room had to be provided for removing the piston and piston rods from the steam pump, the pump had to be located a short distance above the foundation. In the construction of this foundation, which measures 5.55 feet by 2.65 feet at the top and 3 feet by 5.55 feet at the bottom and 2.25 feet high, only 1.3 cubic yard of concrete was used, the total cost of the foundation being only $19.97.

In the selection and installation of this pump, it was attempted in every instance to conform to the rules of the underwriters, and the pump was not contracted for until they had approved it.

The pump has a 5-inch discharge and 6-inch suction as shown on Plate IV. The discharge was increased by means of an extra heavy flanged ell at the pump to 7 inch and run from there to the 12-inch cast iron main. A 7-inch gate and check valve are located directly above the pump. This places the discharge line in a position easily reached by the engineer. The discharge line has a by-pass to take care of the water meter. This meter has an extension dial flush with the engine room floor, thus making it convenient to read.

The suction lines were constructed entirely of cast iron, with cast iron specials, this construction not only gave a minimum depreciation but also reduced to a minimum the friction losses in the suction line. This line was increased to 8 inches at the pump and run practically underground all the way. Gate valves were used exclusively.

TESTS

The pump was in operation for over a month before the preliminary tests were made. Some trouble was experienced at first with packing and one of the bearings, which naturally necessitated operating it longer before making the acceptance test than would otherwise

have been necessary. Making tests of this kind in the field in small plants is quite different from laboratory experiments, where one naturally has all instruments available, as there are many obstacles to be overcome by home made devices.

The preliminary test of this pump was run on September 3, 1915, at which time, many points presented themselves for correction.

The electrical instruments used in making this test were as follows:

Voltmeter No. 10549 0 to 75 volts and 0 – 150 volts, Weston.
Voltmeter No. 13203 0 to 75 volts and 0 – 150 volts, Weston.
Ammeter No. 7879 0 to 25 amperes, Weston.
Ammeter No. 9969 0 to 25 amperes, Weston.
Wattmeter No. 333915 0 to 150 volts and 5 to 10 amperes, General Electric Company.
Wattmeter No. 333916 0 to 150 volts and 5 to 10 amperes, General Electric Company.
Current Transformer No. 1363343 20:1, 100 amperes, General Electric Company.
Current Transformer No. 1363373 20:1, 100 amperes, General Electric Company.

Potential transformers on the switch board were used in the test.

The two wattmeter method of measuring the input to the motor was used, as this method would give us correct results even with considerable unbalancing in the voltage of the three phases. The sum of the two wattmeter readings gives the total power in the circuit. It will be noticed in the test data that one wattmeter reads less than the other. The following method determined whether the readings were to be subtracted or added. One wattmeter was disconnected and the other put in its place, leaving the same terminal of the voltage coil connected to the middle main and connecting the two terminals of one current coil in place of the terminals of the other current coil. The deflection of the reversed wattmeter was not reversed, therefore, the readings were added. Throughout this test no trouble was experienced from the instruments giving negative readings on light loads, and low power factors. The greatest care was exerted to see that all instruments were read accurately.

As the ratio of transformation of the current and potential transformers was 20:1, the total ratio was 400:1, when both of these instruments were used under these conditions.

By looking at the diagram of connections shown on Plate VIII,

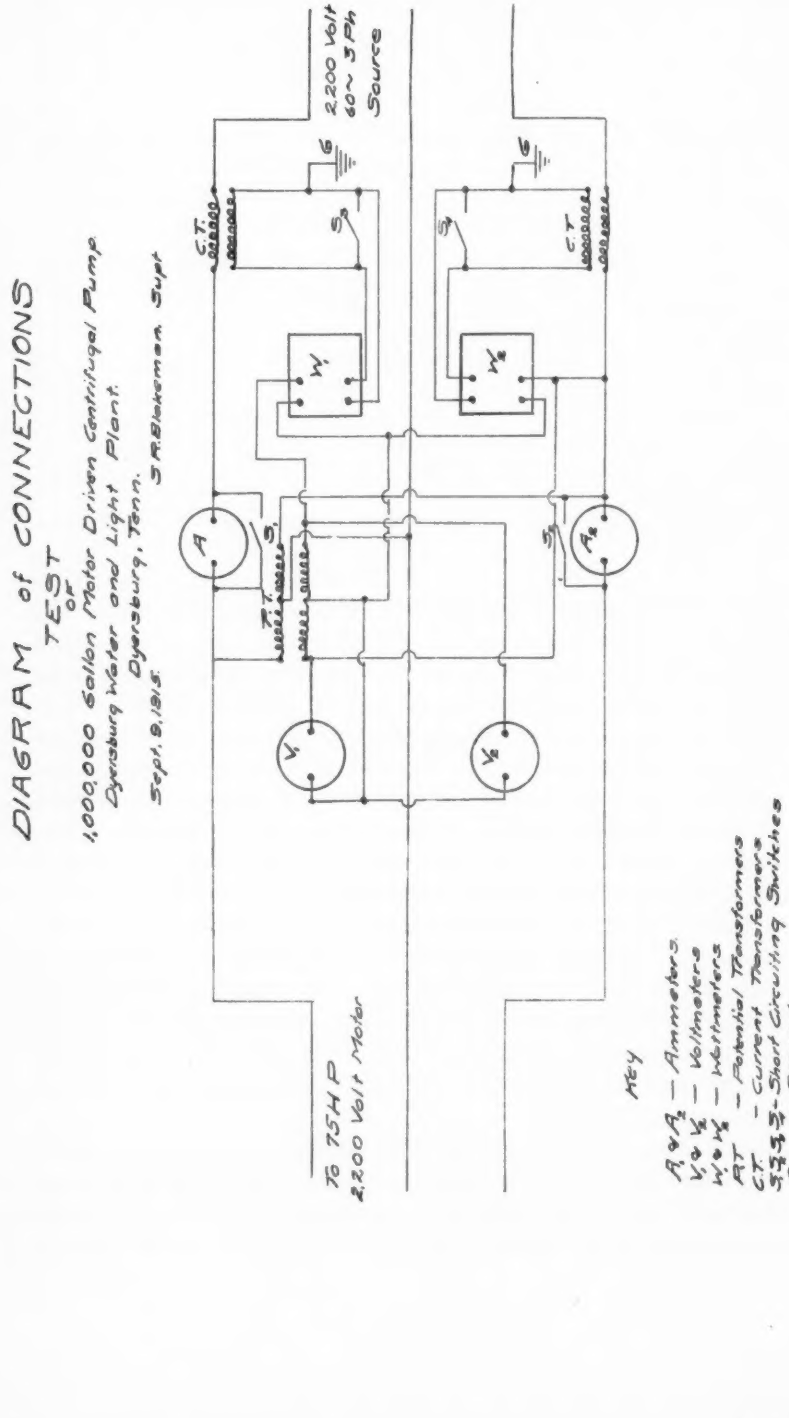


DIAGRAM of CONNECTIONS
TEST OF
1,000,000 Gallon Motor Driven Centrifugal Pump
Dyersburg Water and Light Plant.
Dyersburg, Tenn.
Sept. 9, 1915.
S. R. Blakeman Supt
2,200 Volt
60~ 3 Ph
Source
To 75 H P
2,200 Volt Motor
C.T.
P.T.
KEY
A, & A₂ — Ammeters
V, & V₂ — Voltmeters
W, & W₂ — Wattmeters
P.T. — Potential Transformers
C.T. — Current Transformers
S, S₂ S₃ S₄ - Short Circuiting Switches
G — Ground

PLATE VIII

it will be seen that short circuiting switches were used on both current transformers for short circuiting their secondaries before taking out an instrument. One leg of each of these secondary circuits is shown grounded, thus reducing to a minimum any danger due to handling these instruments.

The weir box was designed to handle 700 gallons per minute, with a velocity of approach not to exceed 0.70 feet per second, giving less than 0.90 feet per second at the maximum discharge of 1000 gallons per minute. Two baffles were provided as shown on Plate IX so as to have the water passing over the weir as free from eddy currents as possible. The sides and bottom of this weir box were carefully braced and tied in as shown by Plate IX. Quite an amount of trouble was experienced with this box at first, due to the settling that took place, when it was filled with water. It was, however, given more bearing surface and checked for settling with an engineer's level. These readings were taken at each end and one at the center of the box for varying depths of water.

For measuring the head of water passing over the weir, at first a glass with a scale attached was used, the zero level having been determined with an engineer's level, but this was not thought to be sufficiently accurate, so two still wells were constructed near the weir box, as shown by Plate X, with a pipe leading into the bottom of the box, this pipe being perforated with $\frac{1}{8}$ inch holes. One of the still wells was equipped with a float gauge, the other being equipped with a hook gauge. This consisted of a $\frac{1}{4}$ inch steel rod with a small pointer attached and a long thread and nut at the top. The readings being taken from a scale, made a part of the still well. The zero readings of these gauges were determined by using an engineer's level.

These two gauges were used as checks on each other. At first, a rectangular notch weir was designed, having a width of 23.6 inches and a height of 14 inches, this being so designed as to take care of a maximum discharge of 1000 gallons per minute. The greatest care was used in the construction of this notch, the sides being made exactly at right angles to the horizontal, having a bevel of 2.25 inches, thus giving the angle of the bevel 22 degrees. This was made from one solid piece of timber, well seasoned, and free from warps the bevel was lined with metal. A detailed drawing of this notch is shown on Plate IX. The piece of timber containing this notch was carefully levelled and fastened to the weir box with

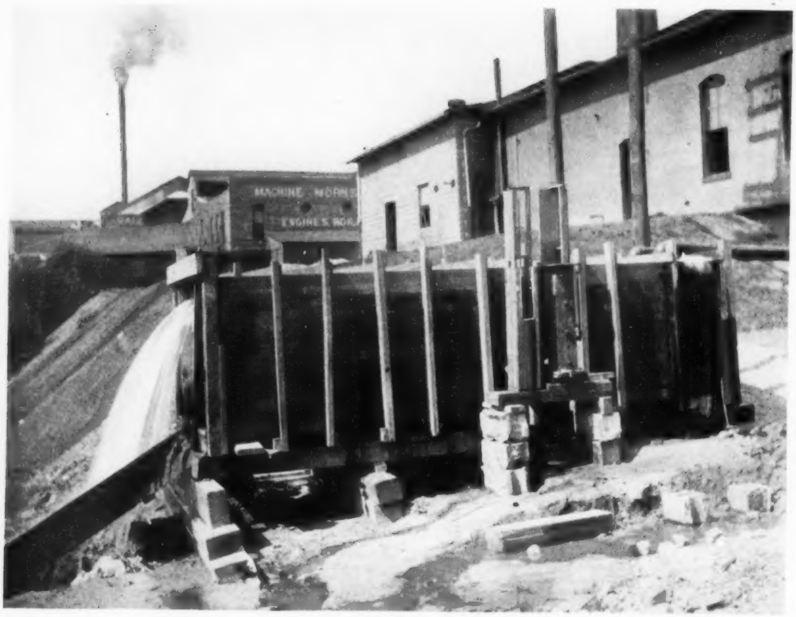


PLATE IX

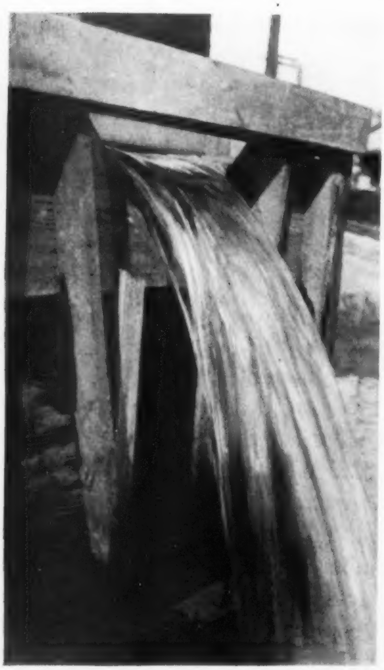


PLATE VI

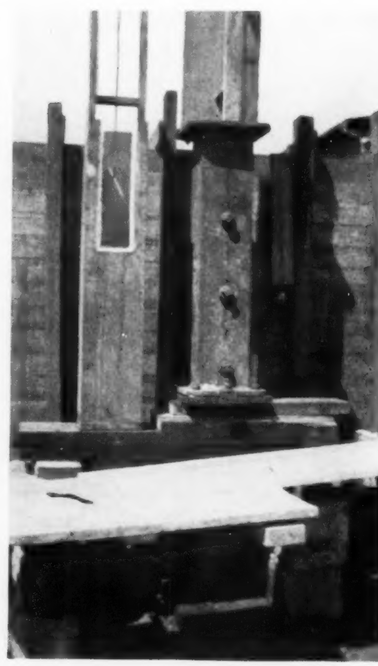


PLATE X

wood screws. Before any tests were made with this notch, the zero point of it was carefully located with reference to the hook gauge. In the calculations made this notch was treated as one having complete and perfect contraction. The following formula being used in arriving at the results:

$$Q^3 = u \times \tfrac{2}{3} \times b \times h \sqrt{2 \times g \times h}$$

where Q = cubic feet per second.
b = width of weir in feet
h = height of weir in feet.
g = 32.2
u = a constant, see table.

The table of constants being as follows:

For b = 0.60 or 23.6 inches

Inches

h	*u*
2.36	0.618
3.15	0.613
3.93	0.609
4.75	0.605
5.90	0.600
7.90	0.592
11.18	0.586
15.70	0.586
19.70	0.586
23.60	0.585

The data obtained from the use of this type of weir tests were not relied upon, or used in the final characteristics obtained, for it was thought that these results were not sufficiently accurate, due to the small volume of water measured. However, the original and calculated data obtained from these tests are included in this report, also platted curves giving an idea as to how they compared with the other tests made.

As the maximum discharge for which this pump was to be tested was 1000 gallons per minute, it was decided to make use of the 90 degree V notch weir, shown on Plate IX, this weir having a depth of 1.2 feet and a width at the top of 2.4 feet, the bevel being the same as used on the rectangular notch weir, this was also designed to take care of a maximum discharge of 1000 gallons per minute.

By using the V notch weir the coefficient of discharge remains constant, a feature not met with in the other weir, it remaining constant from a small head on the apex of the notch to a maximum

which the triangular notch will discharge. Also the ratio of the depth to width is a constant, therefore the influence of end contraction is constant. This type of notch also has the advantage that at small flows, the variations in head are rapid, thus giving a good percentage of accuracy.

In obtaining the zero level of this notch, a very fine piece of metal was made that would just fit into the notch, then just ahead of the pointer a piece of window glass was placed, sealed against leakage. The water was then raised in the weir box until the top of the water

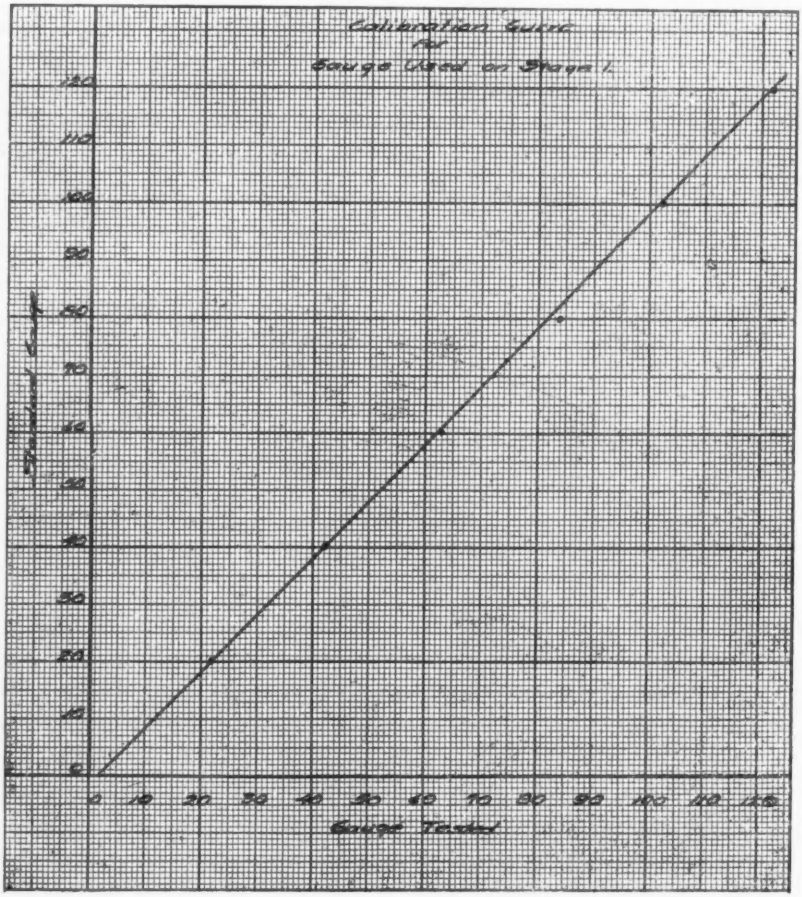


PLATE XI

was level with the top of the pointer. At this point, readings were made on both hook and float gauges. From these readings the length of the pointer was deducted, thus giving us the zero level. It will be noticed in all of the data compiled that both the hook and float gauges checked. Just before using the float gauge, it was given a light tap, so as to avoid any error in reading due to its being stuck. The glass gauge was ignored. All readings were taken in feet.

In making corrections for head due to clear well, a float gauge was used, so arranged as to be read above the filter room floor. The difference in elevation of the pump suction and the bottom of the clear well was determined with an engineer's level.

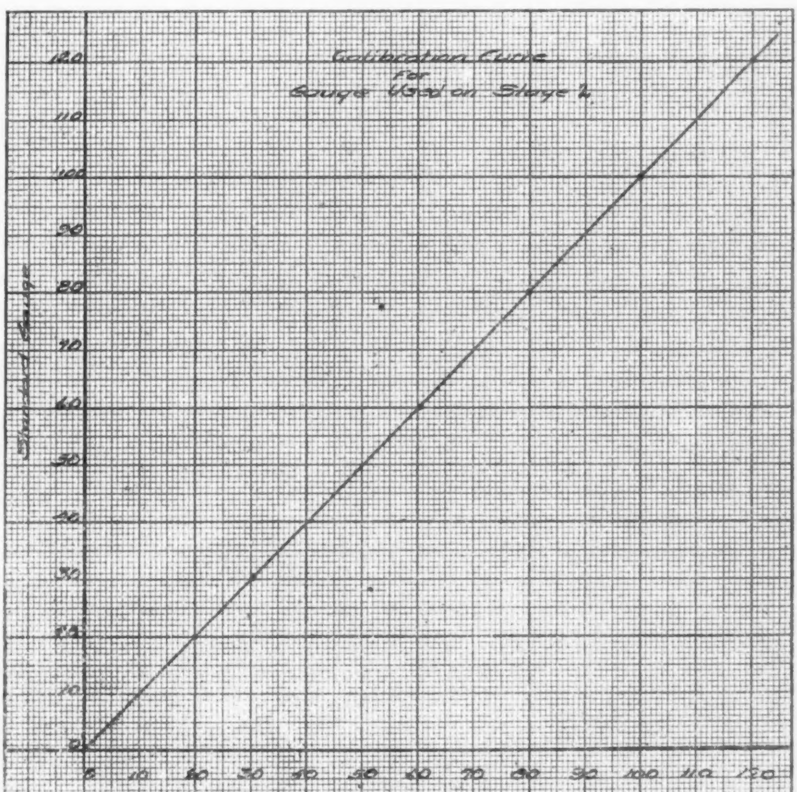


PLATE XII

The pressures in stages one and two were measured with two Ashton gauges, the calibration curve for these gauges is shown on Plates XI and XII. All readings made in this test were made at practically the same time, thereby reducing errors to a minimum.

The calculations made, are shown by following through those for test No. 1, with the 90 V notch weir.

(1) Average volts secondary	=	$\frac{115.5 \text{ and } 114}{2}$	=	114.7
(2) Average volts primary	=	114.7×20	=	2294
(3) Total wattmeter readings	=	86 and 41	=	127
(4) Total watts input	=	127×400	=	50,800
(5) Total k.w. input	=	$\frac{50{,}800}{1{,}000}$	=	50.8
(6) Total h.p. input	=	$\frac{50.8}{746}$	=	67.5
(7) Average current	=	$\frac{15.2 \text{ and } 12.3}{2}$	=	13.7
(8) Power factor	=	$\frac{\text{Watts input}}{\text{Voltage} \times \text{current} \times}$	=	$\sqrt{3}$
or power factor	=	$\frac{50{,}800}{-2294.0 \times 13.7 \times 1.73}$	=	0.94
(9) Head in feet	=	55×2.31	=	127.05
(10) Head corrected	=	$127{,}105 - 7.23$	=	119.8
(11) Hook gauge inches	=	0.95×12	=	11.4
(12) Gallons per minute	=	$0.305\ H\sqrt{H} \times 7.5$		
	=	$0.305 \times 114.4 \times 11.4 \times 7.5$		$\sqrt{11.4}$
	=	1001.2 G.P.M.		
(13) Pounds of water	=	1001×8.33	=	8,343.3
(14) Horse power output	=	$\frac{8345.3 \times 119.8}{33{,}000}$	=	30.3
(15) Efficiency of motor from characteristic			=	0.88
(16) Overall efficiency	=	$\frac{\text{Horse power output}}{\text{Horse power input}}$		
	=	$\frac{30.3}{67.5}$	=	45%
(17) Brake horse power	=	Efficiency of Motor $\times$ Input		
	=	0.88×67.5	=	59.4
(18) Efficiency of pump	=	$\frac{\text{Overall efficiency}}{\text{Motor efficiency}}$		
	=	$\frac{45}{0.88}$	=	51%

The formula for figuring the discharge through the rectangular notch weir has already been given. In the latter part of this report

will be found data sheets showing the original data, and also the calculated results of three tests made in the plant, two making use of the 90 V notch and one using the rectangular notch weir, also the data as furnished by the makers, showing the results obtained from their tests. Following these data sheets will be found the characteristic curve sheets, which are self explanatory.

On each of these characteristic curve sheets there is plotted three different sets of curves, viz, head-capacity, efficiency and brake horse power for the guaranteed curves, before the pump was actually built, the curves obtained on the shop test and the curves obtained from data compiled from the acceptance test. Two of these characteristic curves were obtained from data obtained from the V notch weir in the plant.

It is interesting to note how the guaranteed characteristics were exceeded, as shown by the efficiency curve, and how close the shop test and acceptance test efficiency curve check.

After these data were worked up and curves were plotted, showing that the guaranteed efficiency had been exceeded, a recommendation was made that the unit be accepted. The writer has never before made an acceptance test where the manufacturers guarantee was so completely fulfilled as in this test. All new equipment purchased for our plant is bought under similar guarantees.

After the acceptance tests had been completed, comparative coal tests were made between the steam actuated pump, formally used, and the turbine pump. The results obtained upon this test are shown on Plate XIX. By glancing at these data, the saving in coal between the steam pump and the turbine pump is easily seen.

CONCLUSION

Since the installation of this pump, it has been possible to cut out one boiler for a great part of the day. It has been in operation for nearly eight months, pumping all the water used in Dyersburg, without a single charge for maintenance.

This pump, when given the "Underwriters Test" fulfilled it in every way.

PLATE XIX

Comparative coal tests, steam and Centrifugal Pumps. Dyersburg Water and Light Plant, Dyersburg, Tenn.

TEST NO.	K.W.H. GENERATED	GALLONS OF WATER PUMPED 24 HOURS	POUNDS OF COAL USED	TONS OF COAL USED	PUMP ON	KIND OF COAL	BOILERS ON	DATE
1	2,260	595,410	19,224	9.61	Centrifugal	Nut, pea and slack	4 and 5	Sept. 29, 1915
2	2,200	584,025	18,690	9.34	Centrifugal	Mine run	4 and 5	Oct. 1, 1915
3	1,690	597,675	21,093	10.54	Steam	Mine run	4 and 5	Oct. 2, 1915
4	2,090	540,225	16,287	8.14	Centrifugal	Mine run	4 and 5	Oct. 3, 1915
5	1,720	526,575	19,758	9.87	Steam	Mine run	4 and 5	Oct. 4, 1915
6	1,640	510,525	25,165	12.58	Steam	Nut, pea and slack	1, 2 and 3	Oct. 13, 1915
7	1,680	546,525	25,365	12.68	Steam	Nut, pea and slack	1, 2 and 3	Oct, 14, 1915
8	2,140	561,975	21,894	10.94	Steam	Mine run	1, 2 and 3	Oct. 12, 1915

PLATE XXI

Original data. Acceptance test of 1,000,000 gallon motor driven centrifugal pump. Dyersburg Water and Light Plant, Dyersburg, Tennessee, September 9, 1915.

TEST NO.	VOLTMETER		WATTMETER		AMMETER		GAUGE POUNDS		CLEAR WELL HEAD FEET	WEIR HEADS IN FEET			SPEED IN R. P. M.
	No. 1	No. 2	No. 1	No. 2	No. 1	No. 2	Stage 1	Stage 2		Hook	Float	Glass	
1	115.5	114.0	86.0	41.0	15.2	12.3	30	55	7.23	0.95	0.95		1710
2	115.0	114.0	90.0	35.0	15.8	12.8	30	63	10.40	0.92	0.92	0.84	1680
3	115.0	114.0	87.5	35.0	15.4	12.3	40	74	9.55	0.89	0.89	0.81	1700
4	115.0	114.0	85.0	32.5	15.1	12.0	48	83	9.00	0.87	0.87	0.79	1700
5	115.0	114.0	82.5	30.0	14.7	11.4	50	94	8.45	0.82	0.82	0.74	1740
6	115.0	114.0	80.0	27.5	14.3	10.9	54	102	8.05	0.78	0.78	0.71	1740
7	115.0	114.0	75.0	25.0	13.5	10.2	59	112	7.70	0.72	0.72	0.64	1738
8	115.0	114.0	72.5	25.0	13.0	10.1	60	114	7.40	0.70	0.70	0.63	1743
9	115.0	114.0	65.0	17.5	12.1	8.9	63	120	7.05	0.62	0.62	0.55	1751
10	115.0	114.0	44.0	20.0	3.4	6.0	60	110		0	0	0	1740

Type of weir—90° V notch

PLATE XXII

Calculated data. Acceptance test of 1,000,000 gallon motor driven centrifugal pump. Dyersburg Water and Light Plant, Dyersburg, Tennessee, September 9, 1915

TEST NO.	AVE. VOLTS, SECONDARY	AVE. VOLTS, PRIMARY	WATTMETER, TOTAL	WATTS, TOTAL	K.W. INPUT	POWER FACTOR	H.P. INPUT	SPEED, R.P.M.	AVERAGE CURRENT	HEAD, FEET	HOOK GAUGE, FEET	HOOK GAUGE, INCHES	G.P.M.	POUNDS OF WATER	H.P. OUTPUT	MOTOR EFFICIENCY	OVERALL EFFICIENCY	PUMP EFFICIENCY, %	B.H.P.
1	114.7	2295	127	50800	50.8	0.94	67.5	1710	13.7	119.8	0.95	11.4	1001.2	8343.3	30.3	0.88	0.45	51.1	59.4
2	114.5	2290	125	50000	50.0	0.83	66.6	1680	14.3	145	0.92	11.0	913.3	7611.2	33.3	0.88	0.50	56.8	58.6
3	114.5	2290	122.5	49000	49.0	0.89	65.3	1700	13.8	172	0.89	10.7	837.6	6980.0	36.3	0.88	0.55	62.0	57.4
4	114.5	2290	117.5	47000	47.0	0.87	62.6	1700	13.5	190	0.87	10.4	797.2	6643.0	38.2	0.88	0.61	69.3	55.0
5	114.5	2290	112.5	45000	45.0	0.87	60.0	1740	13.0	215	0.82	9.8	686.5	5721.0	37.2	0.88	0.62	70.4	52.8
6	114.5	2290	107.5	43000	43.0	0.86	57.3	1740	12.6	235	0.78	9.3	600.9	5008.0	35.6	0.88	0.62	70.4	50.2
7	114.5	2290	100.0	40000	40.0	0.85	53.3	1738	11.8	259	0.72	8.6	493.7	4114.3	32.3	0.88	0.60	68.1	46.9
8	114.5	2290	97.5	39000	39.0	0.85	52.0	1743	11.5	262	0.70	8.4	451.8	3765.5	29.9	0.88	0.57	64.7	45.7
9	114.5	2290	82.5	33000	33.0	0.79	44.0	1751	10.5	277	0.62	7.4	343.8	2865.0	24.0	0.88	0.50	56.8	38.7
10	114.5	2290	46.0	18400	18.4	0.60	24.5	1740	7.7	254	0	0	0	0	0	0.88	0		21.5

Type of weir—90° V notch

PLATE XXIV

Original data. Acceptance test of 1,000,000 gallon motor driven centrifugal pump. Dyersburg Water and Light Plant, Dyersburg, Tennessee, September 10, 1915.

TEST NO.	VOLTMETER		WATTMETER		AMMETER		GAUGE POUNDS		CLEAR WELL HEAD FEET	WEIR HEADS IN FEET			SPEED IN R. P. M.
	No. 1	No. 2	No. 1	No. 2	No. 1	No. 2	Stage 1	Stage 2		Hook	Float	Glass	
1	115.0	114.0	92.0	47.5	16.0	14.4	37	57	6.88	0.940	0.940	1.33	1685
2	115.5	114.0	94.0	42.5	16.4	13.6	43	74	7.08	0.915	0.915	1.31	1710
3	115.5	114.0	90.0	42.5	15.9	13.2	47	82	6.85	0.890	0.890	1.29	1711
4	115.5	114.0	85.0	40.0	15.1	12.5	52	93	6.68	0.845	0.845	1.25	1716
5	115.5	114.0	82.5	35.0	14.6	12.0	56	102	6.60	0.810	0.810	1.21	1717
6	115.5	114.0	77.5	30.0	13.9	10.9	60	112	6.53	0.740	0.740	1.15	1730
7	115.5	114.0	75.0	30.0	13.5	10.5	61	114	6.58	0.725	0.725	1.13	1740
8	115.5	114.0	72.5	30.0	13.3	10.4	62	115	6.60	0.710	0.710	1.15	1740
9	115.5	114.0	70.0	26.0	12.8	9.8	64	118	6.68	0.675	0.675	1.08	1743
10	116.0	114.0	65.0	22.5	12.1	8.8	66	123	6.83	0.620	0.620	1.02	1749
11	115.0	114.0	42.5	4.0	9.0	6.4	60	110		0	0	0	1740

Type of weir—90° V notch

PLATE XXV

Calculated data. Acceptance test of 1,000,000 gallon motor driven centrifugal pump. Dyersburg Water and Light Plant, Dyersburg, Tennessee, September 10, 1915

TEST NO.	AVE. VOLTS, SECONDARY	AVE. VOLTS, PRIMARY	WATTMETER, TOTAL	WATTS, TOTAL	K.W. INPUT	POWER FACTOR	H.P. INPUT	SPEED, R.P.M.	AVERAGE CURRENT	HEAD, FEET	HOOK GAUGE, FEET	HOOK GAUGE, INCHES	G.P.M.	POUNDS OF WATER	H.P. OUTPUT	MOTOR EFFICIENCY	OVERALL EFFICIENCY	PUMP EFFICIENCY, %	B.H.P.	HEAD IN FEET, CORRECTED
1	114.5	2290	139.5	55800	55.8	.92	74.4	1685	15.2	132.8	.94	11.28	974.8	8123.5	31.0	.88	.41	46.5	65.4	126
2	114.5	2290	136.5	54600	54.6	.91	72.8	1710	15.0	171.4	.915	11.03	938.0	7816.8	38.9	.88	.53	60.0	64.0	164
3	114.5	2290	132.5	53000	53.0	.90	70.6	1711	14.5	190.3	.89	10.68	834.6	6955.5	38.6	.88	.54	61.3	62.1	183
4	114.5	2290	125.0	50000	50.0	.90	66.6	1710	13.8	215.5	.845	10.14	746.2	6218.3	39.3	.88	.59	67.0	58.6	209
5	114.5	2290	117.5	47000	47.0	.89	62.6	1717	13.3	235.6	.81	9.72	662.6	5580.0	38.7	.88	.61	69.3	55.0	229
6	114.5	2290	107.5	43000	43.0	.87	57.3	1730	12.4	258.0	.74	8.88	522.7	4355.8	33.1	.88	.57	64.7	50.4	251
7	114.5	2290	105.0	42000	42.0	.88	56.0	1740	12.0	262.8	.725	8.7	501.7	4180.8	32.4	.88	.57	65.6	49.2	256
8	114.5	2290	102.5	41000	41.0	.87	54.6	1740	11.8	265.6	71	8.52	480.7	4005.8	31.4	.88	.57	65.3	48.0	259
9	114.5	2290	96.0	38400	38.4	.78	51.6	1743	12.3	272.5	.675	8.1	420.0	3500.0	28.1	.88	.54	61.8	45.4	266
10	115.0	2300	87.5	35000	35.0	.84	46.6	1749	10.4	282.9	.62	7.44	341.2	2843.0	23.7	.88	.50	56.8	41.0	276
11	114.5	2290	46.5	18600	18.6	.60	24.8	1740	7.7	254.1	0	0	0	0		.88			21.8	

Type of weir—90° V notch

PLATE XXVII

Original data. Acceptance test of 1,000,000 gallon motor driven centrifugal pump. Dyersburg Water and Light Plant, Dyersburg, Tennessee, September 17, 1915.

TEST NO.	VOLTMETER		WATT-METER		AMMETER		GAUGE POUNDS		CLEAR WELL HEAD FEET	WEIR HEADS IN FEET			SPEED IN R. P. M.
	No. 1	No. 2	No. 1	No. 2	No. 1	No. 2	Stage 1	Stage 2		Hook	Float	Glass	
1	115.0	113.5	98.0	49.0	17.3	14.5	55.0	35	6.75	0.510	0.510	0.880	1710
2	115.5	113.5	88.0	44.0	15.6	12.9	62.9	33	7.98	0.485	0.485	0.860	1730
3	115.0	113.5	87.5	40.0	15.5	12.4	74.2	39	7.53	0.460	0.460	0.830	1745
4	115.0	113.5	85.0	35.0	15.1	11.6	82.4	43	7.23	0.435	0.435	0.810	1760
5	115.0	114.0	88.0	42.5	15.5	13.0	93.3	53	3.23	0.420	0.420	0.785	1765
6	115.5	113.5	80.0	37.5	14.4	11.5	102.0	57	3.48	0.380	0.380	0.750	1760
7	115.0	113.5	77.0	35.0	13.8	10.7	112.0	59	3.63	0.339	0.339	0.710	1765
8	115.0	113.5	75.0	34.0	13.4	10.9	115.0	60	3.83	0.328	0.328	0.700	1775
9	115.0	113.5	72.5	35.0	13.1	10.6	118.0	62	3.98	0.315	0.315	0.690	1790
10	115.5	113.5	63.0	27.5	11.7	9.1	123.7	64	4.43	0.245	0.245	0.610	1790
11	115.0	113.5	41.0	10.0	9.0	9.6	110.0	60	4.43	0.000	0.000	0.000	1787

Type of weir—Rectangular notch
Height = 14 inches. Width 23.6 inches

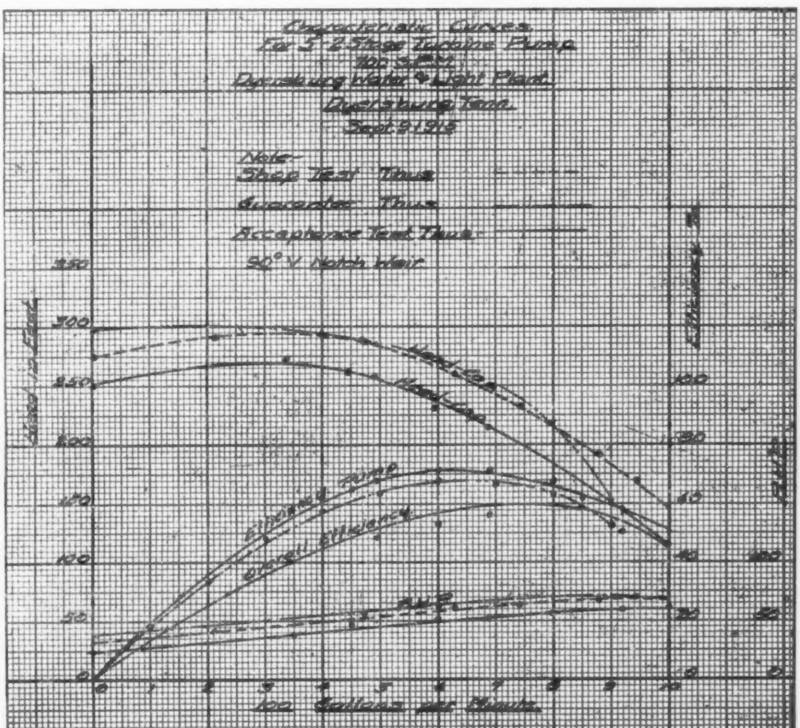
PLATE XXVIII

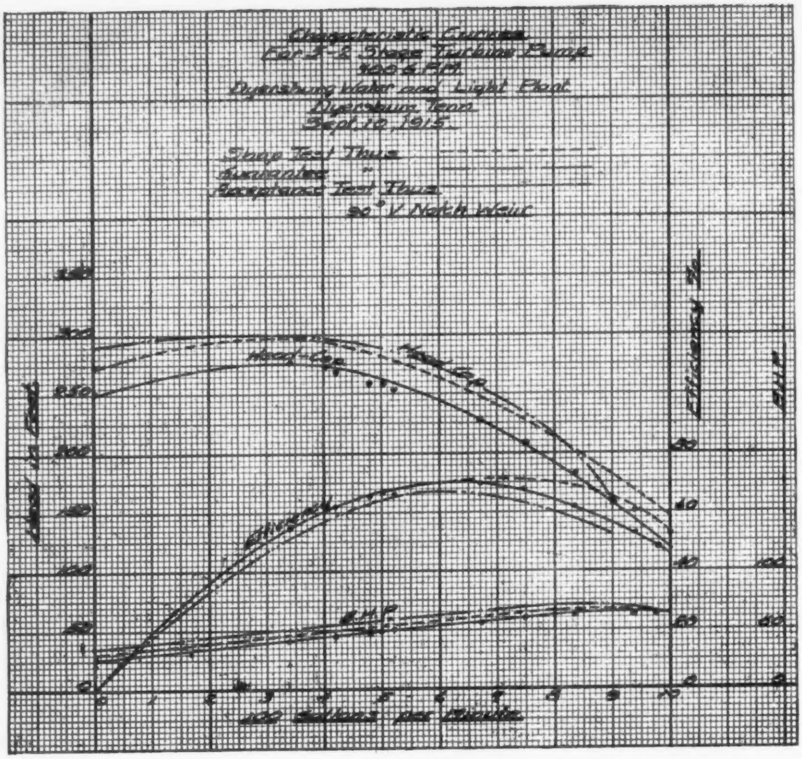
Calculated data. Acceptance test of 1,000,000 gallon motor driven centrifugal pump. Dyersburg Water and Light Plant, Dyersburg, Tennessee, September 17, 1915

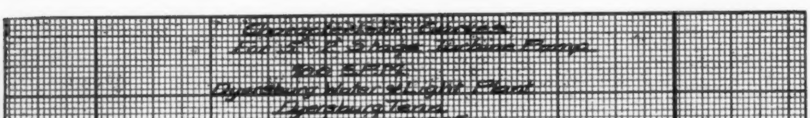
TEST NO.	AVE. VOLTS, SECONDARY	AVE. VOLTS, PRIMARY	WATTMETER, TOTAL	WATTS, TOTAL	K.W. INPUT	H.P. INPUT	AVERAGE CURRENT	POWER FACTOR	SPEED, R.P.M.	HEAD IN FEET	HEAD, IN FEET, CORRECTED	HOOK GAUGE, FEET	G.P.M.	POUNDS OF WATER	H.P. OUTPUT	OVERALL EFFICIENCY	EFFICIENCY MOTOR	PUMP EFFICIENCY
1	114.50	2290	147.0	58800	58.8	78.4	15.90	0.90	1710	127.05	120.32	0.510	1031.4	8595.0	31.3	39.9	0.88	45.3
2	114.25	2285	132.0	52800	52.8	70.4	14.25	0.93	1730	145.29	137.31	0.485	954.0	7970.0	33.1	47.0	0.88	53.4
3	114.25	2285	127.5	51000	51.0	69.0	13.95	0.92	1745	171.40	163.87	0.460	868.5	7237.5	35.9	52.0	0.88	59.0
4	114.50	2290	120.0	48000	48.0	64.0	13.35	0.91	1765	190.34	183.11	0.435	805.5	6712.5	37.2	58.1	0.88	66.0
5	114.50	2290	130.5	52200	52.2	69.6	14.25	0.92	1760	215.52	212.29	0.420	765.0	6375.0	41.0	58.9	0.88	67.0
6	114.25	2285	117.5	47000	47.0	62.0	12.95	0.91	1765	235.60	232.14	0.380	639.0	5325.0	37.1	59.8	0.88	68.0
7	114.25	2285	112.0	44800	44.8	59.7	12.25	0.92	1765	258.70	255.09	0.339	544.5	4537.5	35.0	58.6	0.88	66.5
8	114.25	2285	109.0	43600	43.6	58.1	12.15	0.94	1775	265.65	261.82	0.328	527.8	4398.75	34.9	60.0	0.88	68.0
9	114.50	2290	107.5	43000	43.0	57.0	11.85	0.92	1790	272.58	268.60	0.315	497.2	4143.3	33.7	59.0	0.88	67.0
10	114.25	2285	90.5	36200	36.2	48.2	10.40	.885	1790	285.74	281.31	0.245	335.3	2794.3	23.8	49.3	0.88	56.0
11	114.25	2285	51.0	20400	20.4	27.2	9.30	0.55	1787	254.10	249.76	0	0				0.88	

Type of weir—Rectangular notch

Height 14 inches. Width 23.6 inches




Shop Test Thus
Acceptance Test Thus
90° V Notch Weir
B.H.P.
100 Gallons per Minute


Note —
Shop Test Thus
Acceptance Test Thus
B.H.P.
100 Gallons per Minute

COPPER SULPHATE TREATMENT OF ST. PAUL, MINNESOTA, WATER SUPPLY

By Prof. N. L. Huff

Department of Botany, University of Minnesota

WITH INTRODUCTION BY

Garrett O. House

General Superintendent, Bureau of Water, St. Paul, Minnesota

Water supplied the city of St. Paul is obtained from a series of large and small lakes extending north from the city limits for twenty miles, shown on map page 579. Lake Vadnais, being nearest the city, is used as a natural distributing reservoir, water from the lakes farther north is conducted into Vadnais Lake in quantities sufficient to replenish the water drawn for the city's supply.

In a report to the Board of Water Commissioners in 1915, Mr. Allen Hazen says regarding the quality of the water supplied St. Paul:

> The water in the lakes exposed to the sunlight supports a vigorous growth of microscopic and other plants during the summer. These serve in part as food for larger organisms and animals and, in part, decompose in the water or add to the mud upon the bottoms of the lakes.
>
> As a result of these conditions, the water is subject to disagreeable tastes and odors resulting from the growth and decay of the organisms. It also frequently contains small organisms visible to the naked eye and not agreeable to those who use the water.
>
> The catchment area is occupied by a scattered rural population, with only one small village, Centerville, and the danger of pollution of the water under all the existing conditions is not very great.
>
> With water of this kind, full and accurate knowledge of what growths of organisms are taking place in the reservoirs and lakes is of fundamental importance. This can only be secured by having a suitable laboratory upon the ground. Many of the organisms are fragile and will not bear shipping. Experience shows that samples cannot be sent to an analyst even a few miles away and secure adequate records. A laboratory should be established at Vadnais Lake, in charge of a man who thoroughly understands the organisms that grow in lake waters, and examinations should be made of the waters of the lakes and records kept of all the conditions affecting the quality of the water.

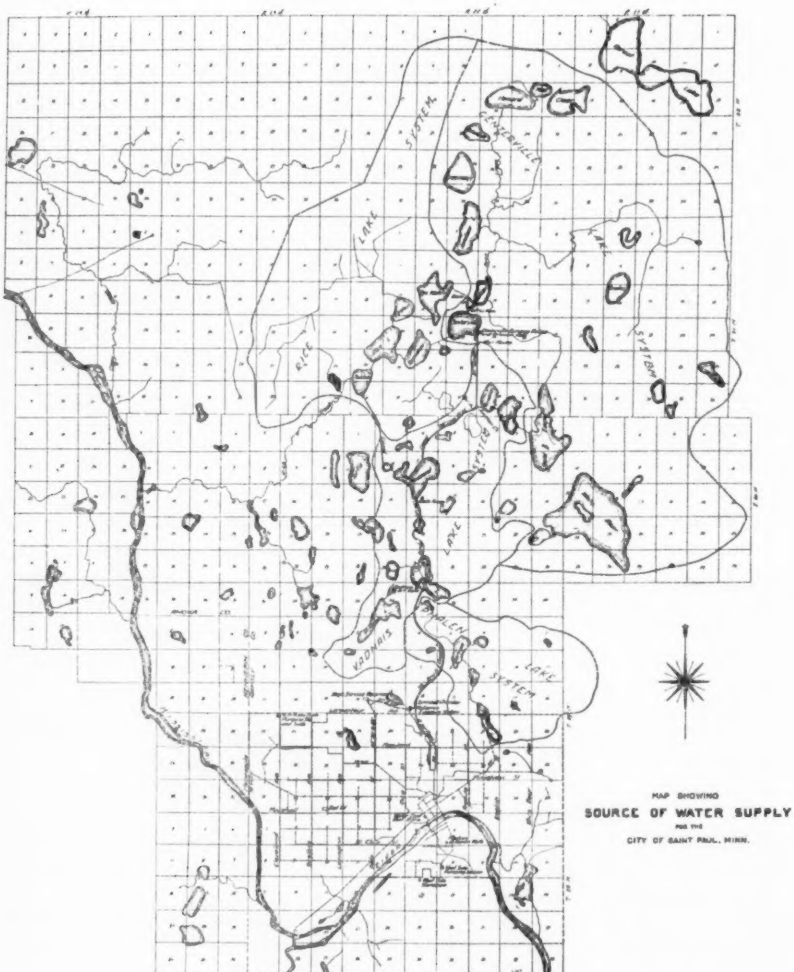

MAP SHOWING
SOURCE OF WATER SUPPLY
FOR THE
CITY OF SAINT PAUL, MINN.
RICE LAKE SYSTEM
CENTERVILLE
VADNAIS
LAKE SYSTEM

FIG. 1

In connection therewith, the use of copper sulphate, tried somewhat experimentally, but successfully, by the department in 1914, may properly be continued and extended. Considerable assistance may be obtained from it with skillful use, and it is particularly important that this should be used to produce all the benefit of which it is capable during the period before filters are installed.

Copper sulphate was applied last year to the water at the outlet of Pleasant Lake, and the water improved by its use went into Vadnais Lake at a point so remote from the intake that little effect was noticed in the quality of the water supply. In carrying out the matter again, it will be better to treat the water in Vadnais Lake itself. This treatment is customary and can be carried out with safety. It must be done, however, under skilled supervision and with care. It is best to kill the objectionable growths as they start and before the organisms have developed so as to form a heavy mass. Applying copper sulphate at the wrong time has sometimes had the result of filling the water with the dead and decaying carcasses of organisms, and has had an effect quite different from that which was intended. The process is useful and helpful, but it requires a high degree of skill to obtain the full measure of benefit from it.

Following Mr. Hazen's recommendations, Prof. N. L. Huff of the Department of Botany of the University of Minnesota, was, in June, 1915, engaged to make a microscopical study of the water supplied the city and supervise its treatment with copper sulphate; to facilitate this work a laboratory was established at Vadnais Lake. The detailed report which follows will, it is hoped, be of benefit to departments and individuals who have a similar problem to deal with.

The cost of each of the three general treatments made was $17.50 for labor and $180 for material.

The efficiency of the treatment is plainly indicated by the materially reduced number of complaints of bad taste or odor from consumers.

Copper sulphate as an algicide is now recognized by water departments everywhere. In a large number of cities where algae or other microörganisms have become troublesome in city water supplies, copper sulphate has been used with success. In many respects its use is beyond the experimental stage. If used in sufficient quantities and under proper conditions it will, without doubt, destroy practically all of the objectionable vegetable growths. The minimum amount necessary to destroy each organism, the particular stage in the life of the individual when the effects of the

FIG. 2. LABORATORY AT VADNAIS LAKE

FIG. 3. BOAT TREATMENT

MAP SHOWING
CONTOURS OF VADNAIS LAKE
ST PAUL MINN. WATER SUPPLY

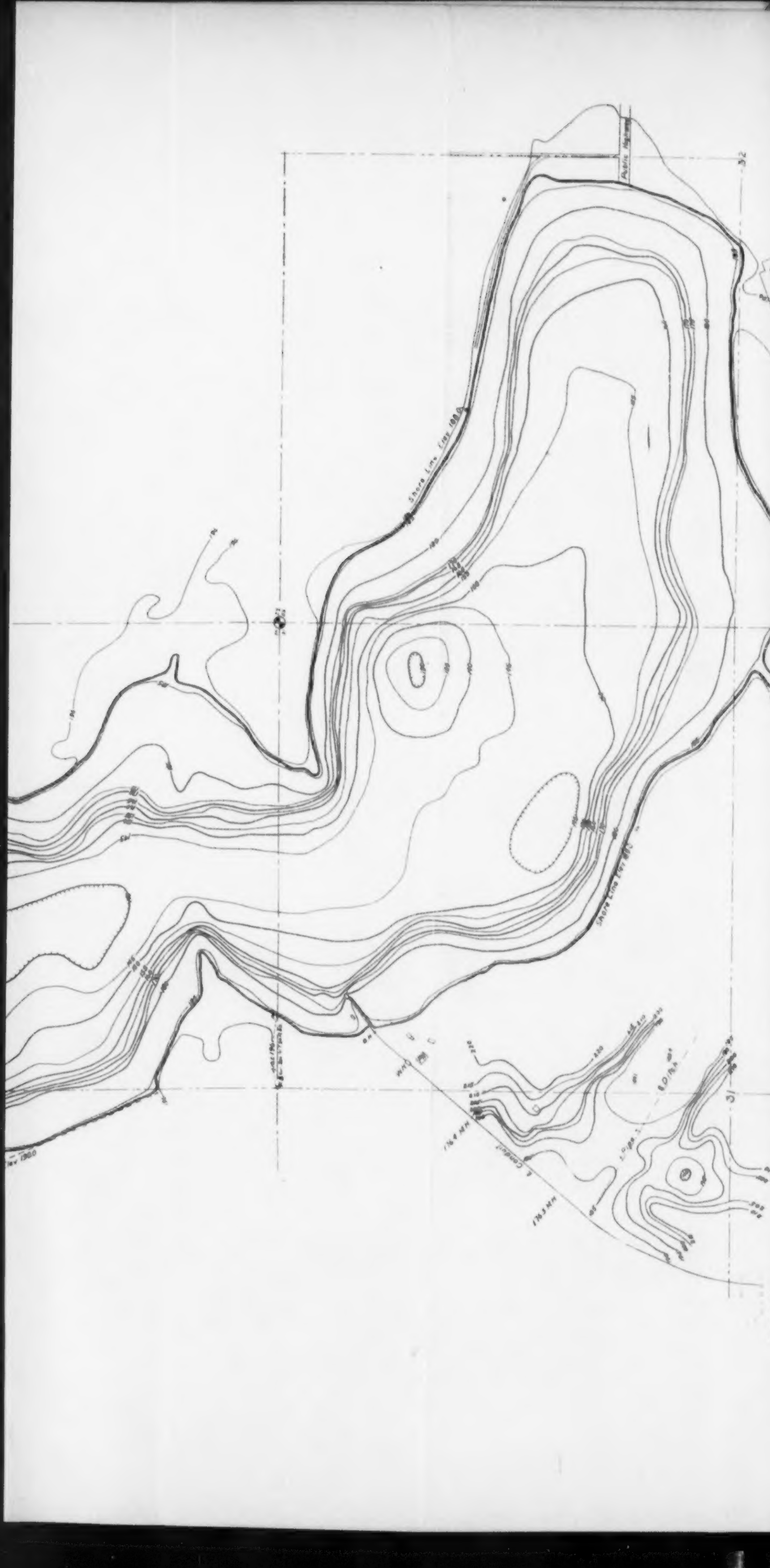


Fig. 4

copper are most deadly, and the exact conditions under which the treatment is most effective for the various organisms, these are some of the problems that are much in need of further study. Each place where the treatment is made offers its special problems. The particular organism causing the trouble may differ in different places. The size and depth of the lake or reservoir to be treated; the temperature of the water; the presence of organic and mineral substances in the water; the size and general nature of the watershed; all these and many other points should be considered when trying to eliminate or control the microörganisms of a water supply system. The experience of others working under similar conditions is always helpful and may be extremely valuable. The number of detailed reports, however, that might be of value to those who wish to make such treatments, is surprisingly small. In many places where treatments have been made the results of the treatment have never been published. In other places the general results are given, but of the exact organisms present, the effect of the treatment upon each organism, the conditions under which treatments were made and other important points little or nothing is said.

The object of this paper is to set forth the effect upon several microörganisms of a series of copper sulphate treatments in Vadnais Lake during the summer of 1915. The lake was given three treatments during the summer, the first June 14, the second July 12, and the third August 27. Besides these general treatments small quantities of copper sulphate were dissolved several times during the summer, in very limited regions along the shore where some particular organism began to accumulate. The study of the organisms was started on June 11, three days before the first treatment, and continued until the lake was frozen over December 11, three and one-half months after the last treatment. Unless otherwise stated, the samples which furnished the material for the following results were collected just above the weir where the water leaving Vadnais Lake enters the conduit leading to McCarron Pumping Station.

Vadnais Lake is located 7 miles north of the city of St. Paul, and has for the most part high well drained shores. The lake is about $1\frac{3}{4}$ miles in length and $\frac{1}{3}$ of a mile in width, covering about 358 acres. Its greatest depth is 57 feet, and the average depth for the entire lake is 27 feet. With the water at the ordinary level, the capacity of the lake is approximately 3,240,000,000 gallons.

The copper sulphate treatments were carried on by the Bureau of

Water, Department of Public Utilities, of the city of St. Paul, for the purpose of destroying the microörganisms which were objectionable in the city water supply. The writer wishes to acknowledge his indebtedness to this Bureau, and especially to Mr. G. O. House, General Superintendent, and Mr. R. L. Smith, Principal Assistant Engineer, without whose assistance and coöperation the work would not have been possible.

The use of copper sulphate for eradicating algae and other objectionable organisms from storage reservoirs and city water supplies, has been practiced for more than ten years. The discovery by George T. Moore, in 1901, of the effect of copper sulphate upon Spirogyra in watercress beds, and the publication by Moore and Kellerman of the Bureau of Plant Industry, U. S. Department of Agriculture, of a couple of bulletins[1] in 1904 and 1905, on the effect of copper sulphate upon bacteria and algae in water supplies, led to quite an extensive use of copper sulphate throughout the country. As early as 1905 the *Journal of New England Water Works*[2] gives a table, compiled from those who had used the copper sulphate treatment, showing the results of many experiments. This table contains definite information on several points, the size of the reservoir treated, the strength of the treatment, the name of one or more organisms causing trouble and the general effect of the treatment upon the organism or organisms causing the trouble. The report covers some 27 cities, representing more than a dozen different states. Both the strength of the treatment and the organism causing trouble varied a good deal in different places. The strength of the treatment was in most cases somewhere between 1 to 8,000,000 and 1 to 1,000,000, and the alga most frequently reported as causing trouble, was Anabaena. The results were almost uniformly favorable, destruction of the troublesome algae and disappearance of all disagreeable taste and odor from the water in a few days. In about one-half the cases cited the algae appeared again the same season, one, two, or three months after the treatment. In several cases where the algae did not occur again during the same season, the treatment was made rather late in the season, in August, September, October, or even as late as November, and the lateness of the season was doubtless largely responsible for their inability to get a second start.

[1] U. S. Dept. of Agr. Bur. of Plant Ind. Bull. 64, 1904, and Bull. 76, 1905.
[2] *Jour. N. E. W. W. Asso.*, vol. 19, 1905, p. 582.

Caird,[3] one of the early workers with the copper sulphate treatment, obtained some interesting results in treatment of reservoirs under normal conditions in 1904 and 1905, and gives in his reports the effect of several treatments of different strength, upon several algae common in the reservoirs treated.

Lovejoy's[4] experiments at Louisville in connection with filter troubles in 1909–1910 are especially interesting. He found in 1909 when several organisms were clogging the filters that by using 14 pounds of copper sulphate per million gallons of water, the filter runs were increased from two hours to the normal of twelve or fourteen hours within three days after treatment. In August, 1910, when filter troubles were caused largely by Synedra and Melosira he found that a treatment of 1.67 parts per million, increased the filter runs from about two hours to a normal of thirteen hours within three days after treatment.

In many places the organisms to be destroyed have been determined before treatment, and the effects of the treatment upon one or more abundant organisms noted in a general way, yet in a very large number of cases where the treatment has been used not even a microscopic examination of the water has been made and the species of algae present or causing the trouble were unknown. Definite and detailed reports giving the conditions under which treatments were made, the strength of the treatment, followed up by the results of the treatment upon various organisms, as can be determined only by regular and frequent microscopic counts of organisms present in the treated water, have in most cases been sadly neglected. The following paper shows the effect of copper sulphate upon several organisms common in Vadnais Lake.

The method used for determining the number of organisms is known as the Sedgwick-Rafter method, and may be described briefly as follows:

A sample consisting of 500 cc. of water is placed in a cylindrical funnel and filtered through a layer of fine sand[5] about 2 cc. in thick-

[3] Caird, Jas. M., Copper Sulphate Treatment for Algae at Middletown, N. Y. *Eng. News*, Jan. 12, 1905, p. 33. Also Copper Sulphate Results, *Proc. Am. W. W. Assoc.*, 1906, p. 249.

[4] Lovejoy, W. N., Filter Troubles Caused by Micro-organisms at Louisville. *Eng. Rec.*, vol. 62, 1910, p. 664.

[5] The sand used for filtering was a medium fine sand ranging from 0.1 mm. to 1 mm. in diameter, though most of it was less than 0.3 mm. in diameter.

ness. This sand strains out practically all organisms. When only 5 cc. of water remain unfiltered, the process is stopped, the sand and water are emptied into a small beaker, and the sand thoroughly rinsed with this water which is then carefully drained off into a clean beaker. The sand is rinsed again, this time with 5 cc. of distilled water, which removes practically all remaining organisms from the sand. The water used for this second rinsing is now mixed with that used for the first, and this is decanted two or three times to free it from all sand particles. This 10 cc. is thoroughly mixed with a pipette, and while the organisms are still uniformly distributed throughout the mixture, a single cubic centimeter is removed and placed in the Sedgwick-Rafter counting cell, for microscopic examination. The Sedgwick-Rafter cell is exactly 1 mm. in depth, and by proper adjustment of the drawtube of the microscope, a Whipple eyepiece micrometer may be made to cover exactly 1 square mm. This will give as a field for counting, exactly 1 cm., and makes the computation very simple. Usually ten counts were made from each sample though when organisms were greatly reduced in numbers so that many cubic millimeters of the concentrated sample did not contain a single organism, one hundred such counts were made, in order to reduce as much as possible, the error arising from the difficulty of picking out typical areas for the count. From the number of organisms found in a given volume of this concentrated sample it is a very simple matter to compute the number in the water as it is found in the lake.

On account of the great variation in size and form of different organisms, and the consequent impossibility of making comparisons between different organisms that would really mean anything, the figures used in the charts or diagrams for indicating the quantity of organisms present, do not refer to the actual number of individuals or colonies of a given organism, but to standard units, a system of measurement suggested by Whipple for convenience in comparing the various forms. The standard unit is represented by a square 20 microns on a side (1 micron equals 0.001 mm.). In computing the number of standard units in a given individual or colony, an attempt has been made to approximate the volume rather than the area of the upper surface. In the majority of cases where individuals are quite uniform in size, the number of individuals was multiplied by a number found to be the average size for that species. In other cases, however, where there was great variation in size, as

in filamentous forms, and forms growing in colonies of an indefinite size, the size was computed separately for each occurrence of the species in the part of the sample counted.

The following lists show the average size in standard units, of several organisms occurring commonly in the waters of Vadnais Lake:

Diatomaceae (Diatoms)

	size
Asterionella	0.5
Synedra pulchella	1.0
Fragilaria	0.25
Melosira	0.25
Cyclotella	1.0
Stephanodiscus	15.0
Synedra ulna	15.0
Epithemia	4.0
Tabellaria	1.0
Navicula	1.0
Pleurosigma	10.0
Amphora	15.0
Nitzschia	0.1
Rhizosolina	0.5
Eunotia	3.0

Protozoa (Simple animals)

Ceratium	10.0
Dinobryon	0.5
Peridinium	6.0
Vorticella	3.0
Epistylis	5.0
Trachelomonas	1.0
Glenodinium	6.0
Paramaecium	20.0
Coleps	3.0
Phacus	3.0
Mallomonas	2.0
Coelomonas	3.0
Uroglena*	
Synura*	

Chlorophyceae (Green Algae)

	size
Eudorina	10.0
Pandorina	3.0
Pediastrum	10.0
Staurastrum	3.0
Cosmarium	5.0
Closterium	20.0
Gloeocystis	5.0
Scenedesmus	0.5
Volvox*	500.0
Raphidium	1.0
Gonium	5.0
Dictyosphaerium*	5.0
Coelastrum	1.0
Docidium	40.0
Dimorphococcus	1.0
Micrasterias	10.0
Richteriella	0.1
Spirogyra*	
Hyrodictyon*, and all other filamentous algae.	

*Cyanophyceae** (Blue-green Algae)

Anabaena*
Clathrocystis*
Coelosphaerium*
Rivularia*
Aphanocapsa*
Aphanizomenon*

* The size of the colony or filament in these forms was estimated for each occurrence in the part of the sample examined, as their variation or indefinite size made averages unreliable.

The method of distributing the copper sulphate in the lake was that which has commonly been employed in such treatments. About

50 pounds of the crystals were placed in a burlap sack, this tied to the stern of a boat and the boat rowed back and forth until the sulphate was dissolved, care being taken to distribute systematically, and as uniformly as possible. In addition to the rowboats which were used near the shore, a small motorboat with a bag of copper sulphate attached to either side, was used for distributing in the central part of the lake.

The following chemical analyses were made by Mr. V. H. Roehrich, Director of the Bureau of Municipal Testing Laboratories, Department of Public Utilities, of the city of St. Paul:

Sanitary Analysis:	*parts per million*	*Boiler Analysis:*	*parts per 100,000*
Suspended matter	3.00	Total solids (dissolved)	16.50
Total solids (dissolved)	165.00	Total hardness	13.30
Chlorine	6.00	Sulphate hardness	0.20
Nitrogen as free NH_3	0.086	Total alkalinity	13.50
Nitrogen as albuminoid NH_3	0.494	Alkali salts	3.00
Nitrogen as nitrites	0.001	Sodium carbonate	0.00
Nitrogen as nitrates	0.480	Foaming rate	Very good
Oxygen consuming power	2.700	Incrusting rate	Very good

The following figures from Mr. Roehrich's report on the determination of copper in water taken from the terminal chamber at McCarron Pumping Station, four miles below Vadnais Lake, show how quickly the copper disappears from the water after a copper sulphate treatment:

About 0.03 parts of copper per million was introduced in Vadnais Lake at 11.00 a.m. on June 14, 1915.

	parts of copper per million
Sample No. 1 taken June 14, 1915, at 5.30 p.m.	0.0005
Sample No. 2 taken June 15, 1915, at 2.30 p.m.	0.0175
Sample No. 3 taken June 16, 1915, at 5.30 p.m.	0.0015

As has been stated by Moore and others it is impossible to give definite figures for the amount of copper sulphate necessary to eradicate a given organism, for several factors must be considered. The temperature of the water, the amount of organic matter present, as well as the presence or absence of various chemical substances such as calcium, magnesium, oxygen and carbon dioxide, etc., probably have their effect upon the amount of copper sulphate necessary to destroy a given organism, and just what part each of these factors plays in the action of the copper sulphate upon algae,

has not yet been determined. The figures, therefore, representing the quantity of copper sulphate necessary to eradicate various organisms vary a good deal with different observers. Moore and Kellerman (U. S. Dept. of Agr., Bureau of Plant Industry, Bull. 76, 1905) give a table based in part upon treatments in reservoirs under normal conditions; Whipple (*The Microscopy of Drinking Water*, p. 255, 1914) gives a similar table, based largely upon Kellerman's figures. These are perhaps as reliable as any that have been compiled. The results of the treatment of Vadnais Lake, however, are so different from the results given by either of these observers that it seems well worth while to direct our attention to a few of the organisms, and their response to the copper treatment here. One of the most interesting organisms in this connection is Synedra pulchella. Moore and Kellerman suggest for the eradication of Synedra the use of one part of copper sulphate in 600,000 parts of water. On June 14, the time of the first treatment with copper sulphate, there were present in the water at the weir as it enters the conduit leaving Vadnais Lake, 3420 individuals of Synedra pulchella per cubic centimeter of water. The treatment[6] given was about one part of copper sulphate to 12,000,000 parts of water, and by June 25, the number of Synedra had dropped from 3420 to 1116 per cubic centimeter. Other organisms present were reduced in a similar manner, but before a month had elapsed, practically all organisms were rapidly increasing again, and it was decided to give a second treatment. This time it was thought advisable to give a heavier treatment so one part of copper sulphate was used for each 10,000,000 parts of water in the lake. This treatment was given on July 14, and Synedra had reached the very high figure of 7720 individuals per cubic centimeter of water. The results of the heavier treatment[7] were surprising. Each day showed a marked reduction in the number of Synedra, and in ten days time the number had dropped from 7720

[6] The amount of copper sulphate used for the entire lake in this treatment was 2250 pounds. The capacity of the lake is 3,240,000,000 gallons, and this would mean about 1 pound of copper sulphate for 1,400,000 gallons of water. Expressed in pounds, we have 2250 pounds of copper sulphate to 27,000,000,000 pounds of water, or approximately one part of copper sulphate to 12,000,000 parts of water.

[7] For this treatment 2700 pounds of copper sulphate were used for the 3,240,000,000 gallons of water in the lake. This would give approximately 1 pound of copper sulphate for 1,200,000 gallons of water, or one part in 10,000,000.

to less than 100 individuals per cubic centimeter. For about four weeks following this, Synedra remained inactive, running from 12 or 15 per cubic centimeter to 100 per cubic centimeter, but not until about August 20 did they begin to show signs of rapid increase in numbers again. This remarkable reduction was secured by a treatment of one part in 10,000,000, or 6 per cent of that suggested by Moore and Kellerman as effective for Synedra. It is true that this treatment did not result in the complete destruction of Synedra. Whether this was due to certain hardy individuals that were able to withstand a treatment of that strength, or to the fact that the copper sulphate was not distributed with absolute uniformity, and some on this account escaped the treatment, we cannot say. With these organisms pouring into the lake, however, in great quantities as they were here through the waters of the inlet, it is doubtful if a treatment of several times this strength would have been effective for more than five or six weeks.

Among other organisms responding to a lighter treatment than that suggested by Moore and Kellerman, may be mentioned Eudorina and Pandorina for which above authors recommend the use of one part of copper sulphate to 100,000 parts of water, and Stephanodiscus for which they recommend one part of copper sulphate to 250,000 parts of water. Eudorina having 100 standard units per cubic centimeter of water practically disappeared within five days after above treatment. Pandorina with 162 standard units per cubic centimeter of water dropped in eight days to an occasional single individual in a sample, and it was more than a month before either of these two organisms began to show any material increase in numbers. Stephanodiscus, which for nearly three weeks had maintained an average of 140 standard units per cubic centimeter of water, almost completely disappeared within a week after the second treatment, and only an occasional individual was found for several weeks following. Late in August a slight increase was noticed but the third copper treatment was given about this time and that put a check upon its development, and for more than another month it was unable to establish itself again. As samples were taken at several points in the lake, also from different depths in the deepest part of the lake, both before and after treatment, and compared with samples taken daily at the weir, it was found that these figures may be considered as representing not the varying conditions of small local areas, but are essentially true for the entire lake surface, as well

as for all depths down to 20 feet or more below the surface. Below a depth of 20 or 25 feet these and other algae were comparatively rare all summer.

About August 20, or more than a month after the second treatment, the organisms, especially Synedra, began to show great increase in numbers. In seven days the total number of organisms increased from 100 standard units per cubic centimeter, to 3952 standard units per cubic centimeter. A third treatment of copper sulphate August 27, of the same strength as the second (1 to 10,000,000), given more than a month before, put a sudden check upon the increase, and brought them down, a little more slowly than before, but by the 14th of September they were again below 100 standard units per cubic centimeter, and remained comparatively low for about another month, many of them not increasing again during the entire season.

During the summer months the water in the bottom of the lake has a temperature of from 10 to 20°F. lower than that of the surface. The maximum temperature for the bottom of the lake was about 59°F., which was reached late in July. The surface temperature was sometimes as high as 78°F. The colder heavier water of the greater depth is not mixed with the lighter water above by ordinary surface disturbances, and therefore becomes quite stagnant during the several months when the surface water is comparatively warm. During September, however, with the short days and cooler nights, the water of the surface of the lake begins to cool and continues gradually until the lake freezes over in December. The water cools of course from the surface, and whenever the surface becomes cooler than the water of the bottom, this cooler, heavier surface water settles to the bottom, and the warmer water of the bottom rises to the surface. This circulation or overturning process will continue for several weeks until the temperature of all of the water in the lake has lowered to 39.2°F., where it reaches its maximum density. In Vadnais Lake in 1915 this overturning process began about September 24, and continued until about November 25. In the early stages of this circulation, some organisms, especially diatoms, were more abundant at the bottom, 50 feet below the surface, than they were at the surface. During the greater part of the circulation period, however, the organisms were distributed nearly uniformly from surface to bottom of the lake. This is very different from their distribution during the summer months when the water near the

bottom of the lake was stagnant, and organisms in large numbers were never found below a depth of 20 or 25 feet.

The great increase of one species of diatom, Stephanodiscus niagarae, during the period of circulation was not entirely unexpected. On the contrary it seems a little strange that some of the other diatoms so common during the summer did not show a similar increase. It is generally known that diatoms increase during the period of circulation of water that follows a period of stagnation. Definite reasons for this phenomenon can not be given until we know the amounts of various materials, organic and inorganic, they require for food, as well as the conditions of temperature light, and air most favorable to their growth and reproduction. It is known that some species of diatom are saprophytic,[8] and it is probable that many of them are able to utilize albuminous or similar nitrogenous compounds from the water in which they live. Dr. Maximilian Marsson[9] is authority for the statement that they can absorb carbon compounds from dissolved organic matter, also organic nitrogen, and when carbonic acid is excluded from the water in which they live, they can digest diluted volatile fatty acids, amidoacids, urea, peptone and other substances. Karsten[10] found that certain diatoms not normally saprophytic could be made so by the proper cultivation in nutrient media. With this information on the food habits of diatoms, it is not difficult to see why the nutritive conditions in a lake like Vadnais are unusually favorable for these forms during the circulation period following several months of stagnation. The following theory for the explanation of the occurrence of maximum growths of diatoms during the circulation period following stagnation in deep lakes is offered by Whipple,[11] and is well worth our attention here: With the decay of organic matter in the bottom, during the stagnation period, the water near the bottom undergoes great changes. Oxygen is exhausted, ammonia and other compounds, both organic and inorganic, increase and are dissolved in the water. With the upward currents during circulation, not only is this water, rich in food materials, carried upward where conditions for diatom growth are more favorable, but the spores, and diatoms themselves which in their inactive condition at least are heavier

[8] West, *The British Freshwater Algae*, 1904, p. 264.

[9] *Eng. News*, Aug. 31, 1911, vol. 66, p. 246 (translation by Emil Kuichling).

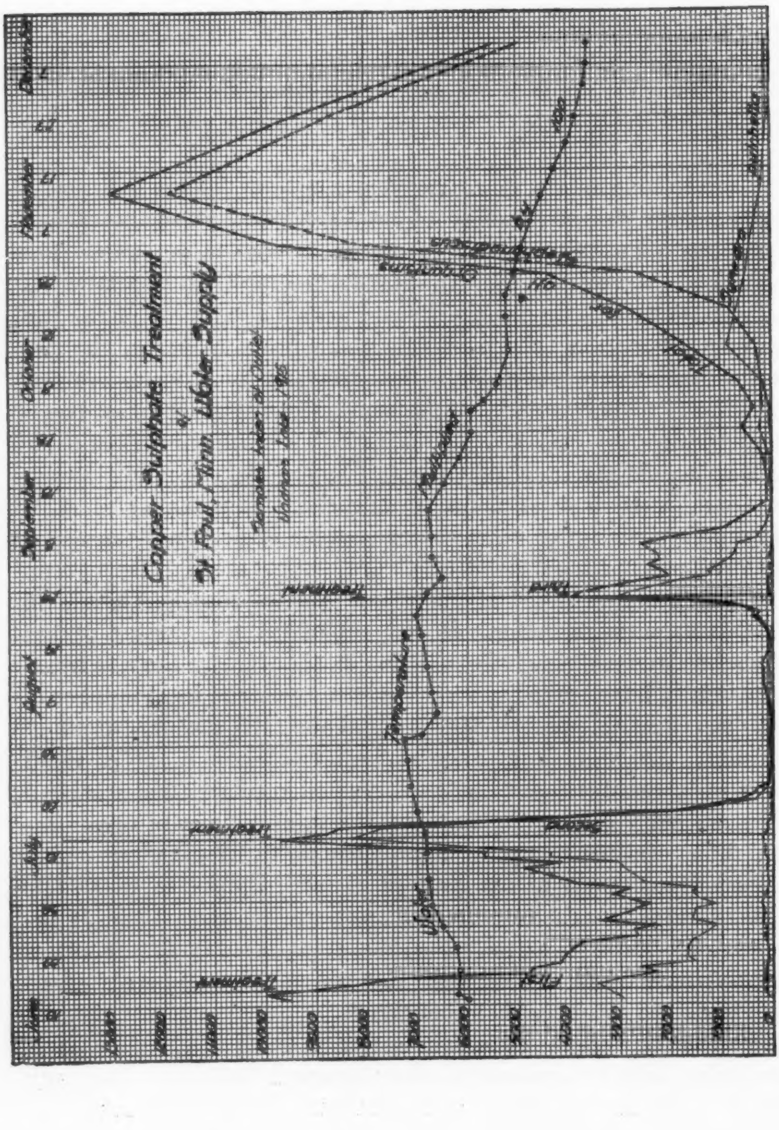
[10] Karsten, G., Ueber farblose Diatomeen, *Flora* 89, 1901, p. 404.

[11] Whipple, *The Microscopy of Drinking Water*, 1914, p. 169.

than water and have lain dormant in the mud of the bottom, where light is too weak, and other conditions are unfavorable for growth, these also are carried upward where light and air conditions are favorable, and with the abundant nourishment now present, they multiply with great rapidity. This perhaps accounts for the high point reached by some of the organisms, especially Stephanodiscus, late in the season while this autumnal shifting of waters was going on.

A brief study of the accompanying charts or figures will give a much clearer idea of the effect of copper sulphate upon the various organisms than can be given perhaps in any other way. The variation in the total of all organisms from June 11 to December 11, is shown in curve 1. This chart also shows the variation of the two diatoms, Synedra pulchella and Stephanodiscus niagarae, the two most abundant organisms, as well as the changes in water temperature for the same period. On June 14, the day of the first treatment with copper sulphate, the total number of organisms per cubic centimeter of water was 8100 standard units. Of these, 3420 standard units were due to Synedra pulchella. The remaining 4700 units were made up of other diatoms, green algae, bluegreen algae, and protozoa, the numbers of which are brought out in other figures. The treatment consisted of about one part of copper sulphate to 12,000,000 parts of water. It was responded to by most of the forms but was not nearly so effective as the slightly heavier treatments given later. Within less than two weeks the total number of organisms had dropped to 2400 with about 1100 standard units of Synedra. Early in July, Synedra began to show a rather rapid increase in numbers, and by July 12, had reached 8260 standard units per cubic centimeter, bringing the total number of organisms per cubic centimeter up to approximately 9700 standard units. A second treatment of one part of copper sulphate to 10,000,000 parts of water brought very decided and satisfactory results. Within ten days after the treatment the total number of organisms dropped from 9700 to less than 100 per cubic centimeter, where they remained for more than four weeks.

The rate of increase or multiplication in some of the diatoms is interesting, and a glance at the chart (curve 1) will show how very rapidly they increase when once conditions become favorable for their growth. The following figures for Synedra pulchella show how it increased in eight days under normal conditions in Vadnais Lake:



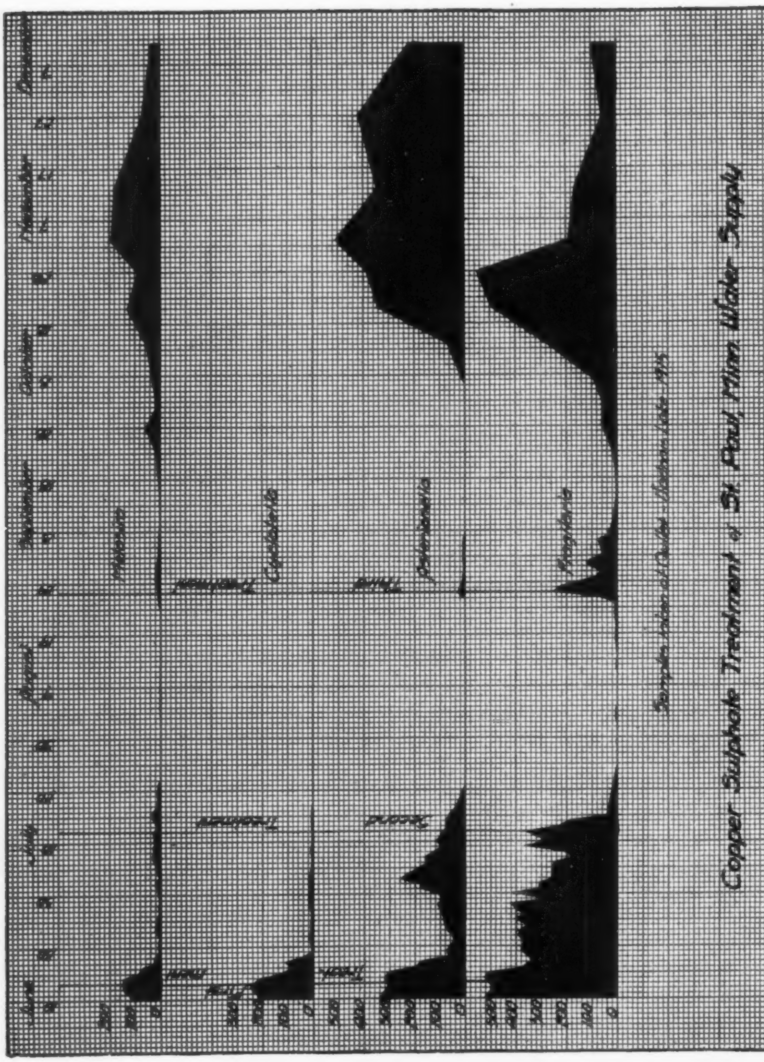
CURVE 1

	Individuals per cubic centimeter
August 19	46
August 20	80
August 21	114
August 23	300
August 24	225
August 25	520
August 26	1,080
August 27	3,020

Judging from these figures Synedra may, under favorable conditions double its number in about twenty-four hours, and at this rate of increase, a comparatively small number surviving after the treatment, or entering the lake through the inlet, after the treatment, will be sufficient to replenish the lake in a very short time.

On August 27, with the total number of organisms about 4000 standard units per cubic centimeter, a third treatment of copper sulphate of the same strength as the second (1 to 10,000,000) was given the entire lake. The reduction of organisms that followed was similar to that of the second treatment, but required about 18 days to bring the number below 100 standard units per cubic centimeter. Synedra and some of the other forms responded much as before, but Eudorina and Pandorina continued to increase in numbers for several days after the treatment and this accounts for the longer time required to bring down the total number to its former position. For more than a month following this reduction in numbers the total number of organisms did not rise above 1000 standard units per cubic centimeter. The latter part of October, however, with the circulation following the stagnation period of the summer months, some of the diatoms showed quite an increase. Most notable among these was Stephanodiscus niagarae which continued to increase until about the middle of November when it reached the very high number of 11,850 standard units per cubic centimeter. When the water temperature of the lake had lowered to 39.2°F. the maximum density for water, and the circulation ceased, Stephanodiscus began to show a reduction in numbers, and by December 11, about the time when the lake became frozen over for the winter, this organism had been reduced to about 4920 standard units per cubic centimeter, and was still going down very rapidly.

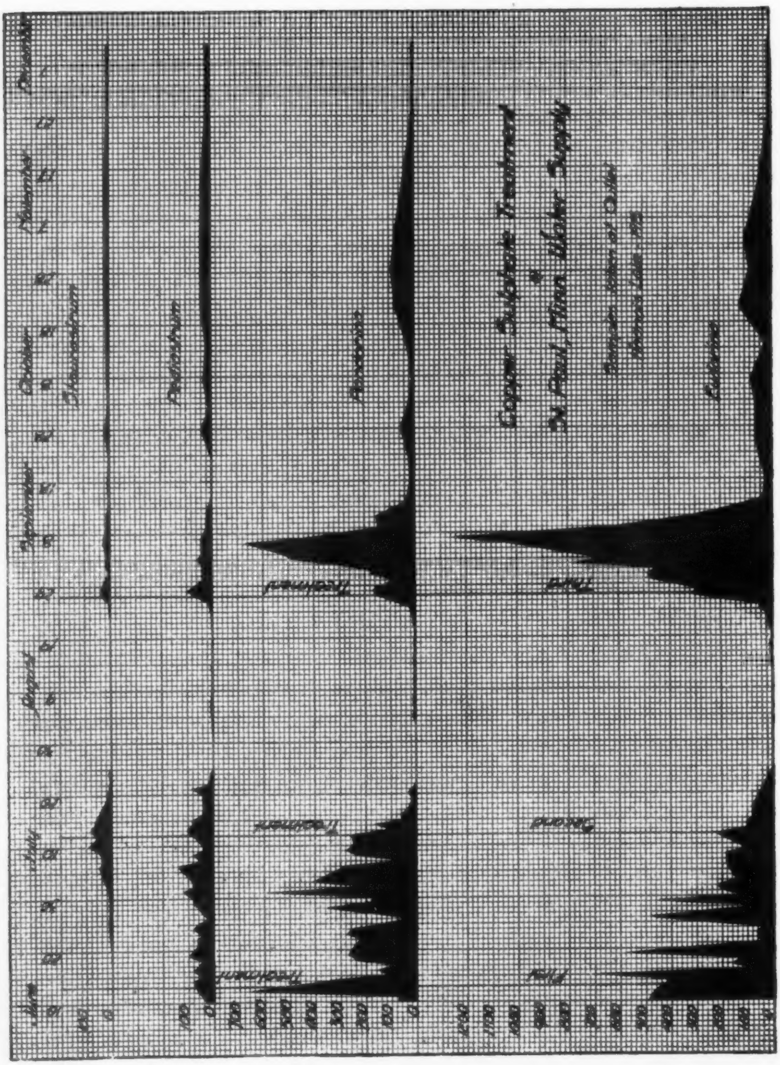
The response of four other diatoms to the copper sulphate treatment is shown in curve 2. These four, Melosira granulata, Cyclo-


Copper Sulphate Treatment of St Paul, Minn Water Supply
Melosira
Cyclotella
Asterionella
Fragilaria
Treatment
Second
Third

CURVE 2

tella comta, Asterionella formosa, and Fragilaria capucina, were the only diatoms, aside from the two mentioned above, that occurred commonly in the main body of the lake. The first copper treatment resulted in the complete elimination of Cyclotella comta for the season. Melosira, which was greatly reduced by the first treatment, was practically eliminated by the second, not to occur in large numbers again until late in September, after the autumnal circulation had begun. Asterionella and Fragilaria were greatly reduced by the first treatment, and practically eliminated by the second treatment. Both of these had made a fair start, however, late in August, but the third treatment cut them down at this time and not until the autumnal circulation of late September and October did they reëstablish themselves in even fairly large numbers. These, like Stephanodiscus, were greatly reduced as soon as the autumnal circulation had ceased, and before the lake had started to freeze over.

The several species of green algae common in Vadnais Lake vary a good deal in their sensitiveness to copper sulphate. Spirogyra, for example which was quite common, from 500 to 600 standard units per cubic centimeter at the time of the first treatment, was entirely eliminated within three or four days after the treatment. Just before the second treatment it occurred again in small quantities, there being from 100 to 150 standard units per cubic centimeter. With the second treatment it disappeared completely and not even a trace of it was found in the main body of the lake the remainder of the summer. Some other forms, however, especially Eudorina and Pandorina, were found to be at times more resistant. These two forms, as is shown in curve 3, were running from 300 to 400 standard units per cubic centimeter at the time of the first treatment. They showed a decided decrease in numbers shortly after the treatment but continued to oscillate a good deal between 50 and 300 standard units per cubic centimeter until after the second treatment, July 12. With this treatment both of these forms and two others that had occurred in smaller numbers, namely Pediastrum and Staurastrum, were practically eliminated, none of them running higher than from 1 to 10 standard units per cubic centimeter until late in August. The third treatment, August 27, was not responded to by Eudorina and Pandorina as quickly as the second treatment had been. Instead of decreasing at once as they had done before, they continued to increase slowly in numbers for about two weeks after the treat-



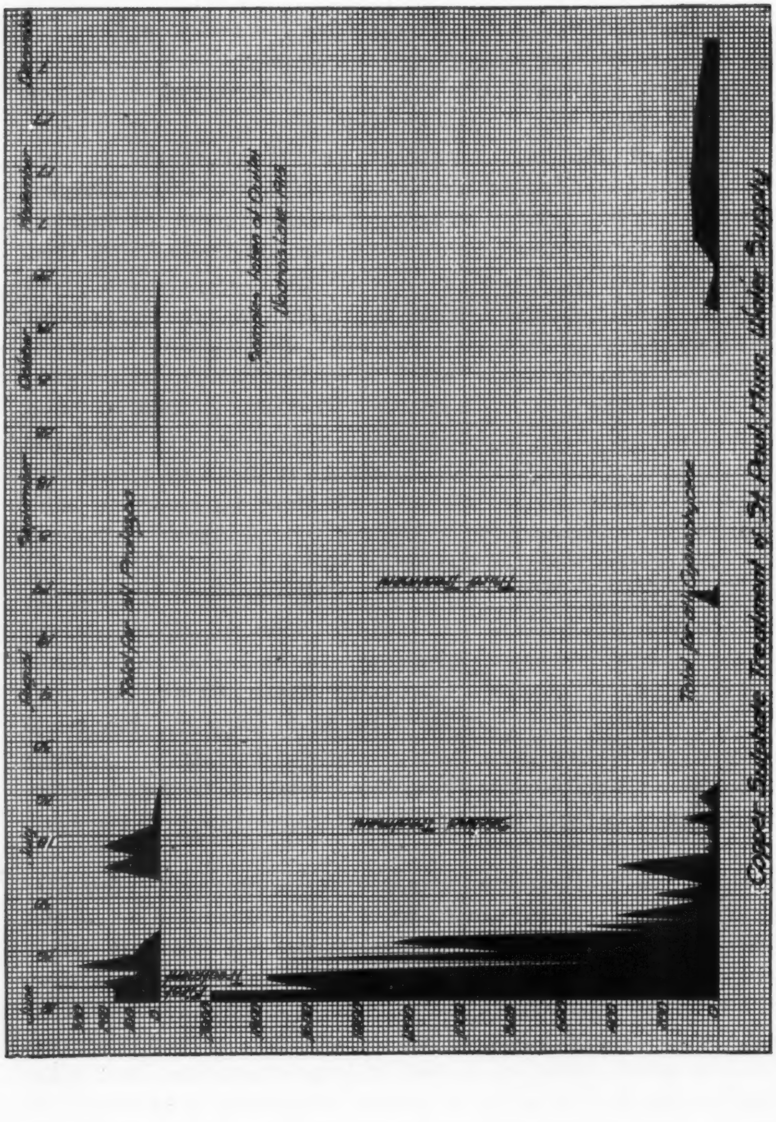
CURVE 3

ment. They were finally forced to succumb, however, and after about two weeks of stubborn resistance, Eudorina with 1,200 and Pandorina with nearly 700 standard units dropped rather suddenly to less than 100 standard units per cubic centimeter each. They did not rise materially again during the season.

Most of the bluegreen algae are very sensitive to copper sulphate. At the time of the first treatment they were running from 1500 to 2000 standard units per cubic centimeter (curve 4), Anabaena oscillarioides being responsible for the greater part of this. The first treatment cut the number down to an average of about 100 standard units per cubic centimeter, and the second treatment eliminated them almost completely. About the time of the third treatment they increased to 100 standard units per cubic centimeter, but were completely eliminated by this treatment, and scarcely a trace of them occurred again until late in October when Aphanizomenon appeared, running at times to about 100 standard units per cubic centimeter, but never found in much larger numbers. Frequent application of small quantities of copper sulphate in a couple of small bays found to be favorite breeding places for bluegreen algae, doubtless helped materially in keeping these forms in check and prevented their spreading to other parts of the lake.

The only protozoa that were at all common at the weir where the water leaves the lake, were Ceratium, Dinobryon, Vorticella and Uroglena. The response of these forms to the copper treatment is shown in curve 4. Running from about 200 to 300 standard units per cubic centimeter at the time of the first treatment, they disappeared for about ten days. They reappeared in similar numbers before the second treatment, but after the second treatment disappeared rather suddenly and only slight traces of them occurred again during the entire season.

The vertical distribution of organisms in Vadnais Lake is a matter of interest and importance. The relative number of organisms found at different depths below the surface will of course vary a good deal, depending upon the organisms present as well as upon certain vertical currents set up in the water at certain seasons of the year, especially during the spring and autumn. When bluegreen slimes or green scums are present in large quantities, the number found at the surface would of course be greatly in excess of the number found at any point below the surface. But in a lake the size of Vadnais conditions are not favorable in the main body of

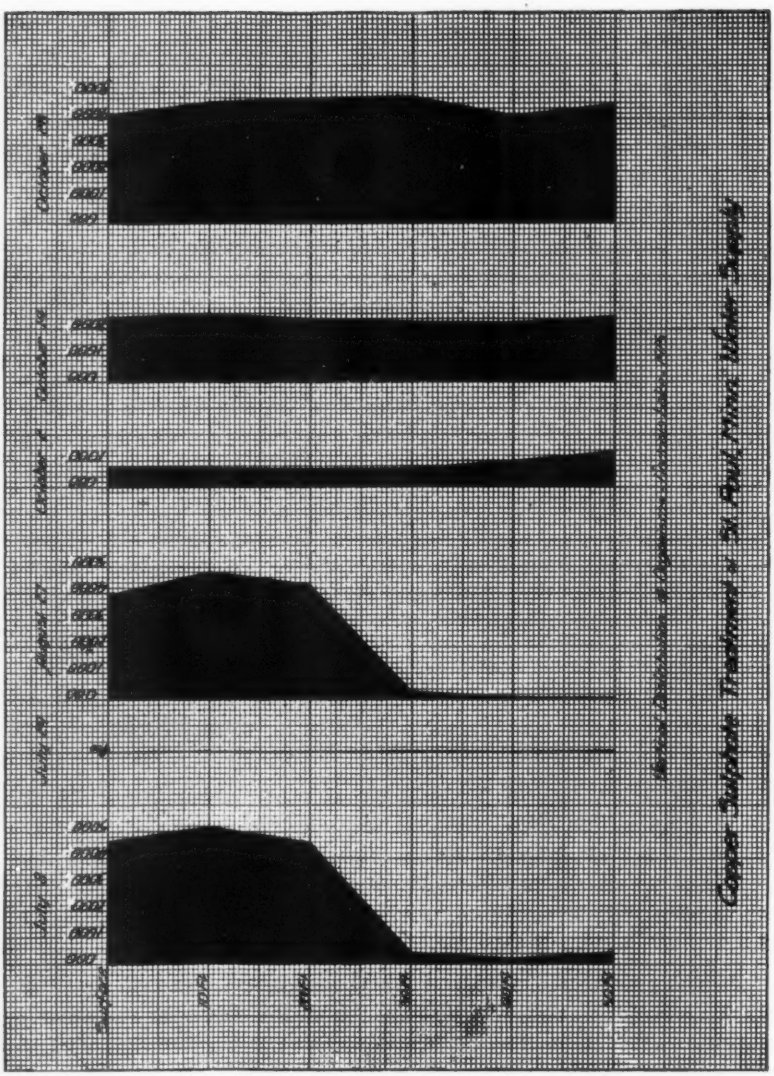


CURVE 4

the lake for these surfaceloving forms. The agitation of the water even by light winds is sufficient to break up the fragile colonies of the bluegreen slimes, and liberate the gases collected in the meshes of the green scums, so that the individual plants or organisms separated from these buoyant gases settle of their own weight to depths where light is too weak and other conditions are unfavorable for growth. With many of the deep water forms, however, it is different. Such forms as Synedra, Stephanodiscus, Eudorina, Pandorina, and others, do not collect in scums at the surface, and are not greatly affected by agitation of the surface waters by the wind. They are usually more abundant a few feet below the surface than they are at the surface. The relative numbers of organisms found at various depths in Vadnais Lake on several dates during the summer and autumn of 1915 are shown in curve 5. The samples for these results were taken near the deepest part of the lake where the total depth was about 55 feet. The number of organisms here near the surface corresponded quite closely to the total number occurring at the weir on the same day. During the autumnal circulation the number was a little larger here than at the weir.

The two series of samples taken on July 8 and August 27, respectively, give perhaps the most normal vertical distribution of organisms for the summer, though at times they were much more numerous than on either of these dates. On July 8 the total number of standard units of organisms per cubic centimeter at the surface was 4656; at 10 feet below the surface, 5186; at 20 feet below the surface, 4591; at 30 feet below the surface the number dropped suddenly to 462; at 40 feet there were 222, and at 50 feet the number was 492. The relative distribution on August 27 was nearly the same as that on July 8, though the number at each level was a little smaller than on the former date. These samples were taken at a time when organisms, particularly diatoms, were increasing very rapidly. The first was taken nearly four weeks, and the second six weeks after a copper sulphate treatment. The thoroughness with which the organisms were cleaned out by the copper treatment may be seen from the samples taken on July 29, two weeks after the second treatment, and about the time when the effects of the treatment were most noticeable. These are the numbers in standard units per cubic centimeter that occurred at various depths on July 29; surface, 19; 10 feet, 34; 20 feet, 22; 30 feet, 63; 40 feet, 28; 50 feet, 60.

The three series of samples taken during the month of October



CURVE 5

show the distribution of organisms during the autumnal overturning of waters in the lake. The first series taken on October 2, shortly after the circulation started, shows organisms, mostly diatoms, to be only about half as abundant at the surface as they are at the bottom. Later they become nearly uniform in their distribution from surface to bottom and probably remain so until the autumnal circulation ceases, meanwhile increasing very rapidly in numbers as they are borne to the upper strata where conditions are favorable for their growth and reproduction.

The following table gives the total number of organisms in standard units per cubic centimeter, as well as the water temperature for various depths, on the dates indicated:

DISTANCE BELOW SURFACE	JULY 8	JULY 29	AUGUST 27	OCTOBER 2	OCTOBER 14	OCTOBER 28
Surface...	4656 69°F.	19 76°F.	3940 68°F.	759 59°F.	2456 52.8°F.	4180 50.8°F.
10 feet....	5186 69°F.	34 73°F.	4815 68°F.	752 59°F.	2602 52.7°F.	4646 50.8°F.
20 feet....	4591 67.5°F.	22 67°F.	4338 67°F.	691 59°F.	2403 52.6°F.	4798 50.8°F.
30 feet....	462 62°F.	62 63°F.	306 61.4°F.	711 59°F.	2295 52.5°F.	4869 50.8°F.
40 feet....	222 59°F.	28 61°F.	88 58.5°F.	996 59°F.	2253 52.5°F.	4127 50.8°F.
50 feet....	492 57°F.	60 59°F.	81 58°F.	1377 59°F.	2495 52.5°F.	4581 50.8°F.

The shores of Vadnais Lake are mostly high, and the banks are rather steep, sometimes sandy, but usually of clay or clay and gravel mixed. At only two or three points in the entire shore line is the shore inclined to be low or marshy, and these low shores are very limited in extent. One of these, at the extreme eastern end of the lake, perhaps 100 yards long and 20 or 30 yards wide and extending parallel with the shore, is covered with a growth of small willows. Here the ground is flooded in the spring and after heavy rains, and pools of stagnant water may be found among the willows at almost any time during the summer. Stagnant water is always a favorable breeding place for organisms, but the particular diatoms and other organisms that were most troublesome in the main lake did not find this a favorable place, and aside from water net (Hydro-

dictyon) which became very abundant here at times, and gradually worked its way out into the shallow water of the lake near by, the lake water near here did not contain a larger number of organisms than at other points along the shore.

A second low shore, more troublesome than the first, is found on the northeast side of the lake, about opposite the gate house. Here a small stream enters the lake through a very small meadow. Between this little meadow and the lake a ridge has been formed, in part by silt and sand carried down by the stream, but largely perhaps by the crowding of ice sheets from the lake. Back of this ridge is a shallow bay, some 200 yards long and 20 or 30 yards wide. This bay is very shallow, varying from the frequently exposed mud flats to a maximum depth of not more than 2 or 3 feet. It lies parallel to the shore line of the lake and opens into the lake near one end through a channel 8 or 10 yards wide. The little stream flows diagonally through one end of this bay, entering the lake through the channel just mentioned. The main part of the bay is perfectly stagnant, and being so very shallow reaches a very high temperature on a warm summer day. It is an ideal place for the growth and reproduction of many algal forms, including Spirogyra and Hydrodictyon which form a scum on the surface. Besides these there are also many smaller, less conspicuous forms such as Diatoms, Volvox, and several of the bluegreen algae, including Nostoc and Gloeotrichia. In certain shallow parts of the bay the bottom is very soft, a muck from 3 to 5 feet in depth not being at all uncommon. When the water is low, much of this area may be covered with a very shallow layer of water, or even completely exposed. In such places numerous organisms accumulate and form dense slimes and heavy scums that give off disagreeable odors and tend to pollute the lake, especially when flushed out into the open water by surface drainage after a heavy shower. On account of the extreme shallowness of the water here, the distribution of copper sulphate by towing a sack of the crystals behind a boat was impracticable. Often considerable areas could not be reached by the boat at all. The abundant dead organic matter, and the mud stirred up by the boat apparently absorb much of the copper and prevent it from spreading any great distance from the path of the boat. The result was that in many places only a few feet from the path of the boat where copper sulphate was dissolved, the scums and slimes continued to grow and reproduce as if no treat-

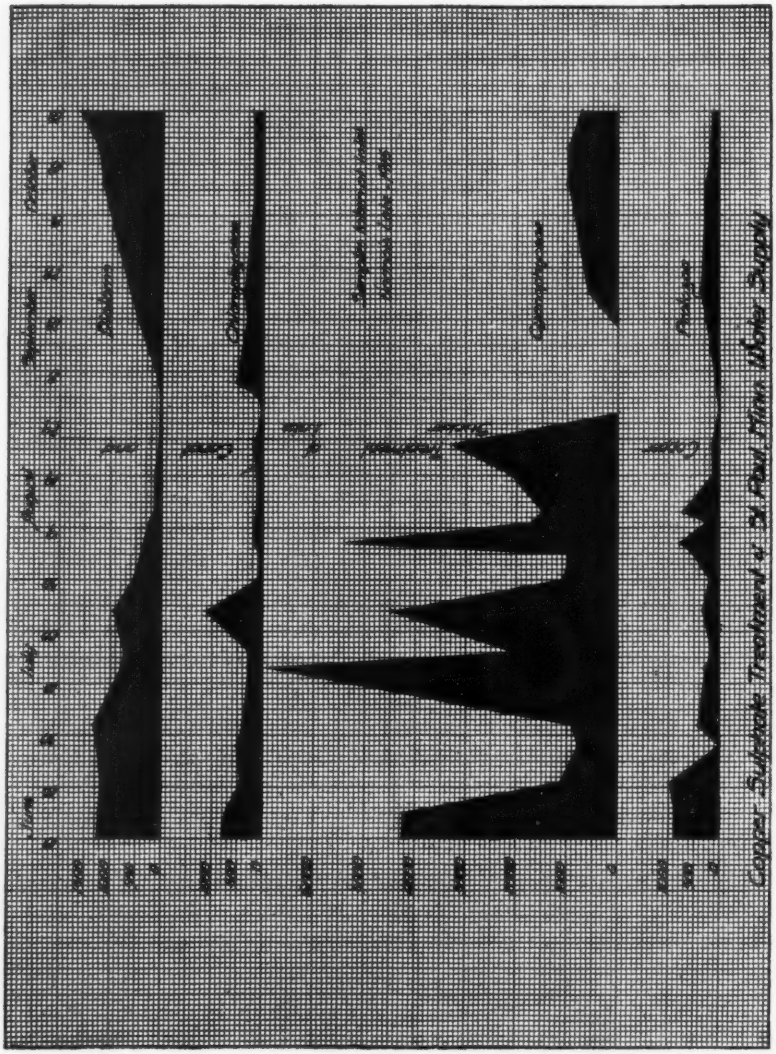
ment had been given. To overcome unfavorable conditions encountered here the spray pump was resorted to and proved to be a most satisfactory and successful means of treating such inaccessible places. The type of pump used was a small hand pump such as is used for washing windows or spraying trees. When used without the spraying nozzle a stream could be thrown 50 feet and many small areas inaccessible by boat were easily reached and thoroughly freed from organisms by a single treatment. The spray pump was also found to be very effective and economical in treatment of green scums such as water net (Hydrodictyon), Spirogyra, and similar forms often accumulating near the shore of quiet or protected bays.

Of the entire shore line, however, the most favorable breeding place for bluegreen slimes is a small shallow bay in the mouth of the inlet, at the extreme north end of the lake. The inlet is about 15 feet wide but when it approaches to within about 200 yards of the lake, it broadens out into a shallow bay, some 50 yards wide. The main channel here is 3 or 4 feet deep and usually has quite a perceptible current, but at either side is shallow and sluggish, and is a favorable place for growth of pond weeds and water lilies, as well as for microscopic organisms. Just before this inlet bay opens out into the main lake, a sandy point juts out from the eastern bank to the edge of the main or deeper channel. On the opposite or western side of this inlet, a very shallow arm of the bay extends westward about 100 yards parallel with the lake shore, being separated from the main lake by a low point. This forms a favorable pocket into which the bluegreen slimes and other surface forms coming in from untreated lakes above, easily drift, especially when there is a slight breeze from the south or east. Here, on account of the warm quiet water, they multiply very rapidly, and constant attention was required here to prevent their spreading to other parts of the lake. On June 16, organisms were found to be quite abundant here. Two samples, one from the middle of the bay and the other from near one side where organisms were evidently more abundant, were examined under the microscope. The first of these showed 2290 and the second 5810 standard units of organisms per cubic centimeter, largely due to green algae. During several days following, the bluegreen algae drifted in from the inlet and a heavy scum accumulated. By June 23 this scum practically covered the entire bay. On this date about 20 pounds of copper sulphate were introduced here. As to the

FIG. 5. SPRAY PUMP TREATMENT

strength of this treatment it is difficult to say, but it was several times heavier than that given the lake nine days before. In two days time not a living alga could be seen in the entire bay. A slight odor due to decaying algae was present, the water while much clearer than it had been before, had a dark color. A microscopic examination failed to show a single algal form present, where two days before there had been several thousand for every cubic centimeter of water. Three forms of protozoa were present in small numbers, but their entire total amounted to only 116 standard units per cubic centimeter, and the amorphous matter suspended in the water was only a small per cent of what it had been a few days before. For about four weeks following this treatment the water here remained clear and comparatively free from organisms, but late in July the bluegreen forms drifting in from the inlet began to show up in great quantities. On July 30 a sample showed more than 40,000 standard units per cubic centimeter, mostly bluegreen algae that had drifted in from the mouth of the inlet. About 25 pounds of copper sulphate introduced at this time cleaned out the algae in three or four days. Great quantities of these organisms were constantly drifting in from the inlet and within a week or so began to accumulate again. A sample taken August 4 showed 700 standard units per cubic centimeter. Another sample taken August 6 showed 51,000 standard units per cubic centimeter. The following day another treatment of 25 pounds of copper sulphate was given the little bay. In two or three days the bay was again free from living organisms. Microscopic examination of the water here was not made again until August 20, but on that date there were but 286 standard units of organisms per cubic centimeter. The water here remained practically free from algae the remainder of the season.

In general the shore line of the lake is very regular, and aside from the three small places above described, there are no stagnant bays or other places along the shore where pond scums and bluegreen slimes find a favorable breeding place. The size and depth of the lake, the high clean shores and the regularity of the shore line all contribute to its adaptability as a reservoir, for which purpose it is used. The control of microörganisms in a lake of this size is quite a problem. Were the lake fed entirely by underground springs it might be less difficult, but Vadnais Lake is supplied by water from a chain of several lakes, some of them of considerable



CURVE 6

size and depth, but many of them small, shallow and with low muddy shores and weedy bottoms. The water of these low shores and shallow bays reaches a very high temperature during the summer, and many organisms, especially several of the bluegreen slimes, multiply here with great rapidity. With the change of winds they drift about and if once carried out into the open lake may be picked up by the sluggish currents and borne down to Vadnais Lake, and thence to the city water mains.

The number of organisms entering Vadnais Lake through the waters of the inlet is enormous (curve 6). During the greater part of the summer, the number of algae entering here averaged more than 4000 standard units per cubic centimeter of water, and with 10,000,000 to 15,000,000 gallons of such water entering every day, it is not difficult to see why several treatments were necessary to keep down the number of organisms at the intake for the city water system. The diatoms and many of the green algae entering here spread throughout the lake, multiplying and increasing rapidly everywhere. For them the deep water offers ideal conditions for growth and reproduction. They move slowly down the lake, dividing and reproducing as they go, and by the time they have reached the gate house, some have increased an hundred or even a thousand fold. Their distribution throughout the entire lake, not merely at the surface, but from the surface to a depth of about 25 feet, makes it possible to control or destroy them only by a treatment of the entire lake.

With the bluegreen algae, however, it is very different. They flourish best near the surface, and prefer the warmer, quieter waters of the shallow bays. Here under favorable conditions they increase with astounding rapidity, some forming a dense scum upon the surface of the water, others suspended near the surface, give a decided bluegreen color to the water, and may be quite uniformly mixed to a depth of several inches below the surface. Should they remain in these breeding places they would perhaps give little cause for alarm. But under certain conditions they may become quite troublesome. A gentle breeze from the right direction sweeps them out into the main lake. If the water of the lake is a little rough, the fragile colonies or masses of the bluegreen forms are broken to pieces, they disintegrate, and in one or two days the lake may be almost completely free from them. Should the weather be calm, however, with just enough breeze to carry the slimes and spread

them over the surface of the lake, but not sufficiently rough to break them up, a bluegreen bloom may develop over the entire surface of the lake, and may accumulate into a definite scum on the leeward side of the lake. A disagreeable odor is usually given off wherever these forms are found in such great abundance. The control of bluegreen algae in a lake like Vadnais, does not seem to be especially difficult. All of these forms that are inclined to be troublesome are exceedingly sensitive to copper sulphate. Whenever they have accumulated in a given locality, in sufficient quantities to be noticeable to the unaided eye, an application of a little copper sulphate to the water will prove very effective. The one part of Vadnais Lake that required constant attention to prevent the spread of these bluegreen slimes was the shallow bay at the mouth of the inlet. Not only was the bay an ideal breeding place for these organisms, but it was being continually replenished by a stream laden with these and other organisms. As stated above, the water entering here contained for the greater part of the summer an average of more than 4000 standard units of organisms for every cubic centimeter of water. Of these 4000 standard units about 2500 belonged to the bluegreen group. On account of the constant change of water in this bay the effects of the copper were not so enduring as in the more stagnant bays, and it was found necessary to treat here about every ten days to prevent accumulations of the bluegreen scums in the stagnant water along the sides of the channel where the inlet opens out into the lake. The effectiveness of these treatments, however, may readily be seen by a comparison of the chart (curve 6) showing the number of bluegreen algae here, with the one (curve 4) showing the number at the weir below the gate house. On June 14, the day when the first copper treatment was given the lake, the number of bluegreen algae in the sample taken at the weir, showed 1780 standard units per cubic centimeter of water. In about ten days they had dropped to 200 standard units per cubic centimeter, and about July 20 disappeared entirely. From that time to the end of the season, these organisms were almost completely absent from the waters of the weir, though late July and August is the very time when they should have been most abundant. At the inlet they continued to pour in, their numbers ranging from 2000 to 6000 standard units per cubic centimeter until August 27 when a heavy copper treatment given the canal and Sucker Lake above Vadnais put a stop to their entrance here for a couple of weeks.

After this the cool weather of late September and October kept them in check and they did not rise above 1000 standard units per cubic centimeter the remainder of the season.

In order to get a better idea of the effect of copper sulphate upon the various organisms found in Vadnais Lake it may be well to compare the numbers of some groups entering the lake at the inlet (curve 6) with those in the water leaving the lake as indicated by figures 1 to 4. The two most abundant forms in Vadnais Lake, namely Synedra pulchella and Stephanodiscus niagarae, are forms that prefer the deep water, and while they enter the lake in small numbers, the explanation for the very large number occurring at times in Vadnais Lake is to be sought in the conditions existing in this lake, favorable to their growth and reproduction, rather than to any large number that may be found pouring into the lake at any one time through the inlet.

Of the four groups of organisms entering the lake, the Cyanophyceae or bluegreen algae are usually most numerous, and appear to be, as a group, most sensitive to the copper sulphate. For about ten weeks during the summer they ran from 1000 to 7000 standard units per cubic centimeter at the inlet, with an average for this period of about 2500 standard units per cubic centimeter. At the outlet of the lake they were running about 2000 standard units per cubic centimeter at the beginning of this period, but after the first treatment, they rapidly disappeared and during the last six weeks of this period scarcely a trace of them was found. On August 27, at the time of the third treatment of Vadnais Lake, the creek entering the lake, and Sucker Lake, a small lake a short distance above Vadnais, were treated, and for the first time during the summer the organisms practically disappeared from the waters of the inlet. Although the treatment here was considerably heavier than in Vadnais Lake, the effects were of shorter duration, for the smaller size of Sucker Lake and creek, permits a more rapid displacement of the treated water, by untreated water from above.

From June 10 to August 27 the average number of organisms in the inlet of Vadnais Lake, was more than 4000 standard units per cubic centimeter. Compare these figures with the number found in the samples taken at the weir below the gate house, especially for a period of about five or six weeks following the copper sulphate treatments of the lake, when the number here was below 100 standard units per cubic centimeter, and the effectiveness of a treatment of 1 to 10,000,000 can not be questioned.

While many organisms appeared at one time or another during the summer in the waters of Vadnais Lake, and disappeared, probably as a result of the copper treatment, many of them were not found in sufficiently large numbers to justify a statement concerning the exact effect of copper sulphate upon their existence. With several others, however, that were more common there can be no question as to the effect of copper sulphate. The following forms were found before one or more of the treatments in sufficient numbers to justify certain conclusions concerning the effects of the treatment as here given:

Chlorophyceae. (Green Algae)
- Spirogyra sp.
- Eudorina elegans Ehr.
- Pandorina morum (Mull.) Bory.
- Pediastrum duplex Meyen.
- Staurastrum sp.

Diatomaceae. (Diatoms)
- Stephanodiscus niagarae Ehr.
- Synedra pulchella (Ralfs.) Kg.
- Fragilaria capucina Desmaz.
- Asterionella formosa Hass.
- Cyclotella comta (Ehr.) Kg.
- Melosira granulata (Ehr.) Ralfs.

Cyanophyceae. (Bluegreen Algae)
- Anabaena oscillarioides Bory.
- Anabaena flos-aquae (Lyngb.) Breb.
- Clathrocystis aeruginosa (Kuetzing) Henfrey.
- Coelosphaerium Kuetzingianum Haegeli.
- Aphanizomenon flos-aquae (Linn.) Ralfs.
- Rivularia echinulata (Smith) Born. and Flah.

Protozoa. (Animal Forms)
- Ceratium longicorne Carter.
- Dinobryon sertularia Ehr.
- Uroglena volvox Ehr.
- Vorticella communis Ehr.

From observations made on above mentioned forms, the results of which are for the most part shown in accompanying diagrams or figures, the following conclusions may be drawn:

1. With conditions under which above treatments were made, the use of one part of copper sulphate in 12,000,000 parts of water is quite adequate for the elimination of Spirogyra, Cyclotella, and most of the Cyanophyceae. It will practically eliminate Melosira and the four protozoa here listed; for the other forms above mentioned it will bring about great reduction but may not eliminate them.

2. The use of 1 part of copper sulphate in 10,000,000 parts of water is effective in practically eliminating all forms mentioned in above list, with the possible exception of Eudorina and Pandorina, and with the conditions under which the treatments were made this amount is entirely adequate for their suppression.

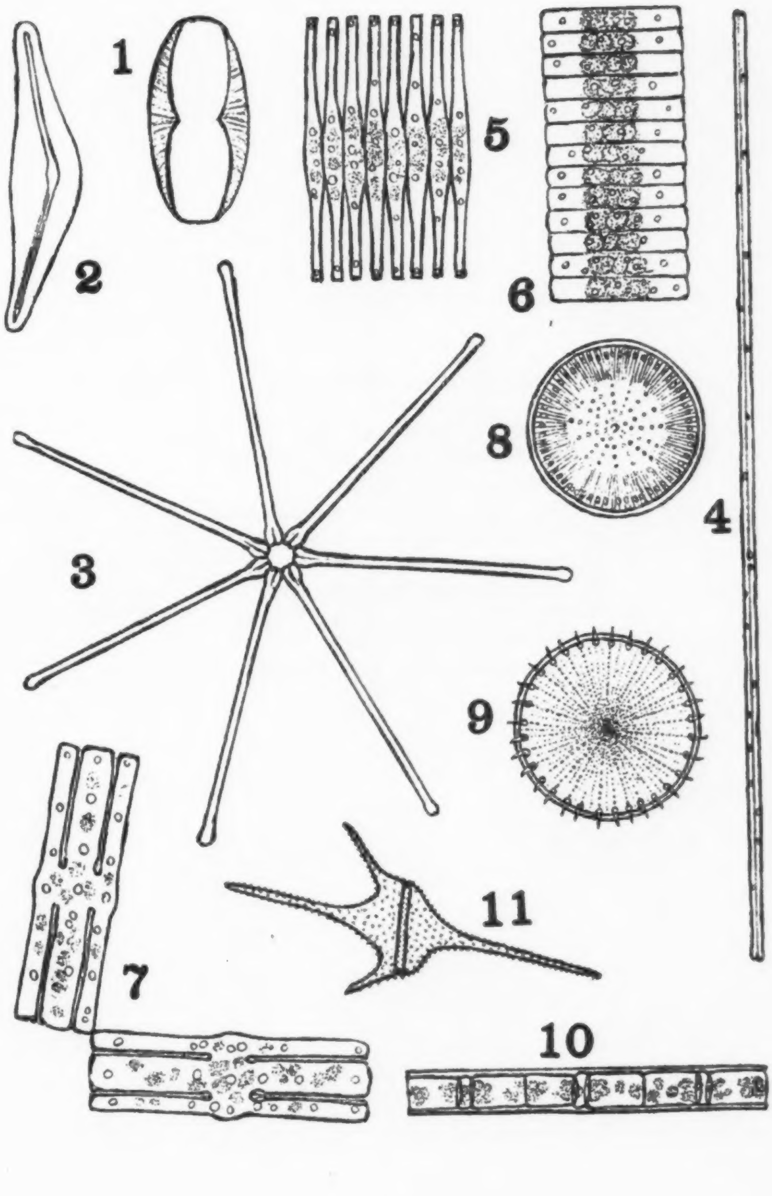
3. With conditions under which above treatments were made, a treatment of one part of copper sulphate in 10,000,000 parts of water remains effective for about five weeks, after which time the organisms present, or many of them at least, seem to find conditions favorable for their growth and reproduction, and if the treatment is not repeated at this time they may increase again with remarkable rapidity.

4. Where quiet shallow bays afford breeding places for numerous organisms, or where any one or more organisms become abundant in small or limited areas, local treatment, or the application of small quantities of copper sulphate to the particular spot where the trouble is originating, has been found very effective. If careful attention is given to such areas, and accumulations of organisms prevented here, the number of general treatments necessary to keep the lake clean for the entire season may be lowered and the total cost of treatments materially reduced.

5. For treatment of very shallow bays, flat muddy shores and small ponds the use of a hand pump such as is used for spraying trees is a practicable and economical means of distributing copper sulphate. In addition to spreading the solution in places inaccessible for a boat, this method has the advantage of leaving the water unroiled and gives the organism the full effect of the copper, much of which might otherwise be absorbed by mud and organic matter stirred up by a boat in such places.

Explanation of Plate I

1. Amphora ovalis (Bréb.) Kg.
2. Cymbella lanceolata (Ehr.) Kirchn.
3. Asterionella formosa Hass.
4. Synedra ulna (Nitzsch.) Ehr.
5. Synedra pulchella (Ralfs.) Kg.
6. Fragilaria capucina Desmaz.
7. Tabellaria fenestrata Lyngb. Kg. var. intermedia Grün.
8. Cyclotella comta (Ehr.) Kg.
9. Stephanodiscus niagarae Ehr.
10. Melosira granulata (Ehr.) Ralfs.
11. Ceratium longicorne Carter.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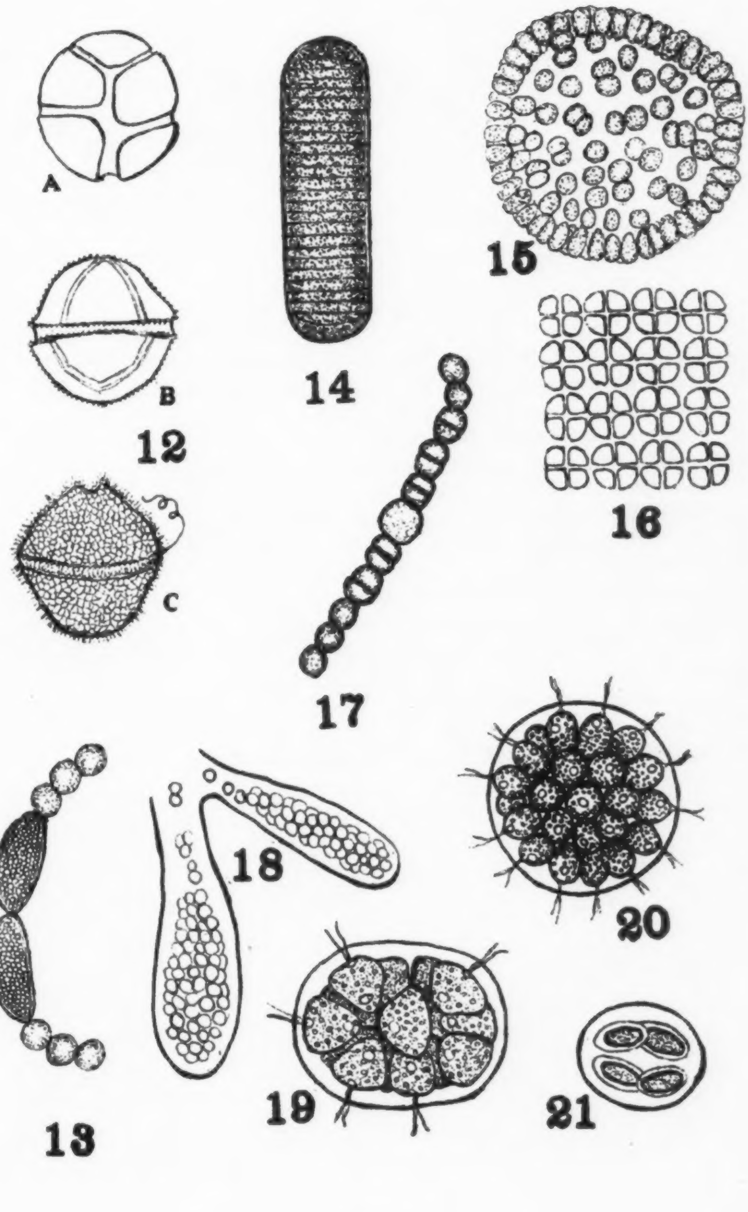
Explanation of Plate II

12. Peridinium tabulatum Ehr.
13. Anabaena flos-aquae (Lyngb.) Bréb.
14. Lyngbya majuscula Harv.
15. Coelosphaerium kützingianum Naeg.
16. Merismopedia glauca Naeg.
17. Nostoc sp.
18. Anacystis marginata Menegh.
19. Pandorina morum (Muell.?) Bory.
20. Eudorina elegans Ehrenb.
21. Gloeocystis gigas (Kg.) Lagerh.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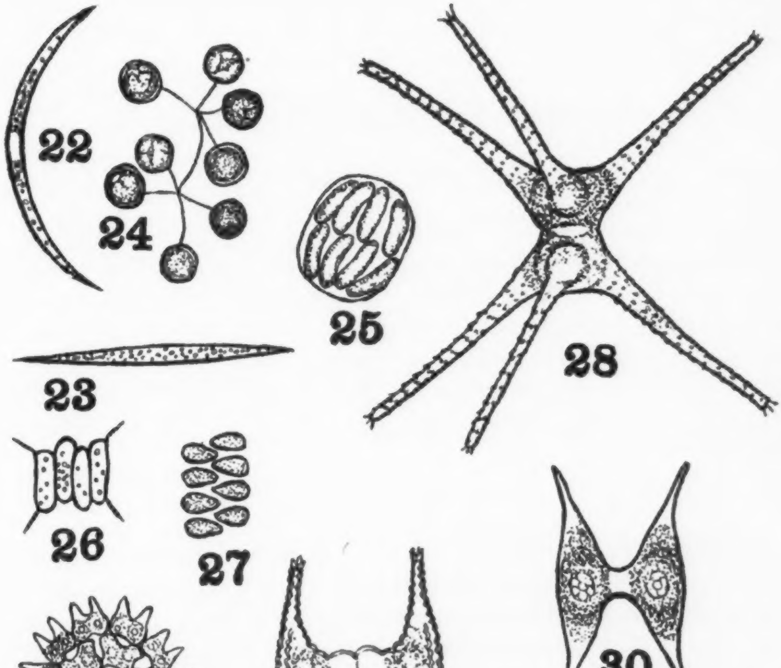
Explanation of Plate III

22. Rhaphidium polymorphum Fresen. var. falcatum (Corda) Rabenh.
23. Rhaphidium polymorphum Fresen. var. aciculare (A. Br.) Rabenh.
24. Dictyosphaerium pulchellum Wood.
25. Nephrocytium agardhianum Naeg.
26. Scenedesmus quadricauda (Turp.) Bréb.
27. Scenedesmus bijugatus (Turp.) Kg.
28. Staurastrum paradoxum Meyen. var. longipes Nordst.
29. Staurastrum sebaldi Reinsch.
30. Arthrodesmus incrassatus Lagerh.
31. Staurastrum minneapoliense Wolle.
32. Pediastrum duplex Meyen.
33. Pleurotaeniopsis quaternaria (cordst.) De Toni.
34. Micrasterias truncata (corda) Bréb.
35. Cosmarium nitidulum De Not.
36. Closterium parvulum Naeg.
37. Coelastrum microporum Naeg. var. speciosum Wolle.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WATER WORKS RESERVOIRS

By Dabney H. Maury

It is the purpose of this paper to describe briefly the several classes of water works reservoirs and explain their respective uses and limitations; to touch upon the value of the proper location of reservoirs, and especially of distributing reservoirs; to discuss the governing considerations in reservoir design; to describe some of the difficulties encountered in actual construction, and to give some suggestions, born of experience, which may help others to overcome these difficulties.

CLASSES OF RESERVOIRS

Broadly defined, a reservoir is a place in which something is kept in store. In water works reservoirs that which is stored is water.

An impounding reservoir is usually formed by building a dam across a stream, so that its waters may be conserved, especially at time of flood, for release during periods of drought. Such reservoirs may be used to store water for power purposes, or for irrigation, or to diminish the danger of damage from floods; but none of these uses would have any relation to water works. If, however, they store water for fire protection or domestic use, they may properly be classed as water works reservoirs.

Other water works reservoirs include what are known as suction reservoirs, storage basins, clear water reservoirs and distributing reservoirs. The first three of these are generally designed to store water which is pumped into them from wells or streams, or which flows into them from filters or settling basins.

Distributing reservoirs are connected to the water distributing system, usually in such a manner that the elevation of the water in the reservoir controls the pressure on the distributing mains. Such reservoirs are naturally built on high ground, and when they are made of steel in the form either of standpipes or of elevated tanks, their flow lines are frequently 100 feet or more above the surface of the ground on which they are located.

In any water works system there are usually a number of steps which lie between the taking of water from its original sources and the actual delivery of it to the consumer. These steps include some or all of the following:

(a) The collection and storage of the water of a stream in an impounding reservoir.

(b) The pumping of water from a stream or lake or from wells to a suction reservoir, or to a settling basin, or to filters, or directly into the distribution system.

(c) The purification of the water either by sedimentation, or by filtration, or by both.

(d) The pumping of the water from the surface reservoir, or from the sedimentation basin, or from the clear water reservoir of the filters, into the distribution system.

(e) The actual delivery of the water from the distribution system to the various consumers.

FIELD OF USEFULNESS

The usefulness of any reservoir depends upon, and is limited by, the position which it occupies in the order or procession of the steps just enumerated.

For example, if it be an impounding reservoir it can do no more than store the waters of the stream above it, and is of no value in conserving or helping out the capacity of the low lift pumps which take their supply from it; or of any suction reservoir, or filter plant, or clear water reservoir, which may follow it; or of the high lift pumps; or of the distribution system. If it be a suction reservoir or clear water well, then it will help out the capacity of everything back of it, which may be a stream, an impounding reservoir, wells, or low lift pumps taking water from any of these sources and delivering it into the reservoir under consideration, or a water purification plant which may discharge into it. Such a reservoir does not, of course, conserve the capacity of the high lift pumps which draw from it, or of the distribution system into which its waters are discharged.

A distributing reservoir, located on the discharge side of the pump and connected to the distribution mains, has more of these steps back of it than any of the other reservoirs just enumerated, and its usefulness may include the conservation of the capacity of stream,

or of impounding reservoir, or of wells, or of sedimentation basins, or of filter plant, or of low lift pumps, or of high lift pumps, or of all of these together.

A distributing reservoir properly located will, in addition to all of the foregoing, help out the capacity of the distribution mains themselves, and this last and very important function has in the past been frequently overlooked.

It follows from what has just been said that the nearer a reservoir is to the beginning of the order or procession of the successive steps in water supply, the less will be its value, other things being equal; and that the further along in this procession of steps, the greater will be the value of the reservoir.

VALUE OF PROPER LOCATION OF DISTRIBUTING RESERVOIRS

In order to derive the greatest possible benefit from a distributing reservoir, it should be properly located; and the intrinsic value of the proper location of such reservoirs has not always been appreciated in the design of water works systems. Where small water works plants have elevated storage, one frequently sees the tank located on the pumping station lot. A tank so located is in most cases a monument to the bad judgment of the man who designed the plant.

To illustrate the point, two cases, out of many that could be mentioned, will be cited:

In the first case the main pumping station was two miles north of the center of the congested value district in a small city. The elevated storage reservoir, originally built close to the pumping station, had been destroyed, and it was necessary to provide a new one.

For the purpose of computing the friction losses it was assumed that a fire broke out during sprinkling hours on a hot day in summer and that the plant would be required to furnish water at the rate of 4000 gallons per minute, distributed throughout the city for domestic consumption, in addition to a supply of 2000 gallons per minute for fire service, which latter amount would be drawn at or near the center of the congested value district. It was found that if the tower and tank were located close to the pumps at the northern end of the city the pressure remaining in the mains in the congested value district would be only 25 pounds, whereas with the same elevated tank

located near the southern end of the town the pressure remaining in the mains would be more than 53 pounds. To save this difference of 28 pounds by laying additional mains from the pumping station to the congested value district would have involved an expenditure of at least $30,000; so that it may be fairly stated that the advantage obtained in this case by locating the elevated storage near the center of the congested value district instead of at the pumping station was worth not less than $30,000.

In the second case, which involved a city of larger size than the one just mentioned, a site for an elevated reservoir of a capacity of 7,500,000 gallons had been selected on an eminence opposite the main pumping station. The congested-value district in this city was comparatively small, and its center was more than three miles south of the pumping station. A topographic map had been made of the proposed reservoir site, and test pits had been sunk through the top soil to bedrock, when the writer was called into pass upon the suitability of the topography and soil conditions for a reservoir of the capacity contemplated. It was at once apparent that the location of the reservoir with regard to the pumping station, to the distribution system of mains and to the territory to be supplied, was far from being a desirable one. An examination was made of high ground opposite the congested value district, with the result that a much more suitable site was discovered, which was later purchased by the city.

For the purpose of comparing the friction losses incident to the reservoir site originally chosen with those incident to the site recommended by the writer, it was assumed that the rate of domestic consumption during sprinkling hours on a hot day would be 3500 gallons per minute, which quantity of water would be distributed throughout the city, and that in addition to this 4000 gallons per minute would be required to meet the demands of a fire near the center of the congested value district.

The computations showed that had the reservoir been located opposite the pumping station the total friction losses would have been 96 feet, or about 41½ pounds, whereas with the reservoir located near the center of the congested value district the friction loss under otherwise similar conditions would be only 3 pounds. The computations further showed that to reduce the friction loss to 3 pounds under the assumed conditions of demand, by putting in additional mains, would have cost more than $200,000. The expenditure of so

large a sum of money would, of course, have been out of proportion to the benefits obtained, and the best economy would have dictated spending less money and putting up with somewhat greater friction losses. On the other hand, it would not have been economical to make the additional main smaller than 20 inches in diameter, had it been necessary to reduce the frictions by this method. The cost of even a 20 inch main would have been more than $80,000. This sum is, therefore, considered to represent the lowest possible estimate of the advantage possessed by the site finally adopted for the reservoir over the one which had originally been chosen.

GOVERNING CONDITIONS IN RESERVOIR DESIGN

Among the first points to be determined are the location, capacity and elevation desired. These having been at least approximately determined, the work of designing may be begun.

The importance of proper location has already been discussed.

On the principle that one cannot have too much of a good thing, the capacity of the reservoir should be made as large as the finances of the local water department will permit. In any event, however, the reservoir should be made large enough to tide over the demand of the four or five hours of maximum consumption, and, if possible, its capacity should at least be equal to a full day's pumpage.

The elevation would be influenced by a number of conditions, the chief among which would be the topography of the city and the height and character of the buildings to be served. If pressure is increased during fires, it may often be found advisable to install an electric driven booster pump taking its water from the reservoir and pumping into the mains, the pump to be started when the fire alarm is turned in.

Generally speaking, where the elevation required is high and the capacity small, the reservoir will be an elevated tank supported by a tower, the whole structure usually being of steel. Other things being equal, that type of tank in which the average elevation of the stored water is highest is to be preferred; and when such tanks can be secured, as at present, at relatively low cost and in safe and attractive designs, it would seem that the old fashioned tall standpipe in which three-fourths of the contained water served no useful purpose except to support the remaining upper one-fourth, has no longer any right to exist. Where larger capacities are re-

quired, and where the flowline of the reservoir does not have to be far above the surface of the ground, the choice in most cases naturally falls on reinforced concrete as the material for the reservoir.

One point which frequently has to be decided is whether or not the reservoir shall be covered. One advantage of covering the reservoir is that the water is more easily protected against pollution, although it is usually possible so to fence and otherwise safeguard an open reservoir that the danger of pollution from the outside is almost negligible. Another minor advantage is that the roof will keep the temperature of the stored water more uniform, and prevent ice in winter and overheating in summer. Perhaps, however, the best service rendered by the roof would be the prevention of algae by the exclusion of the rays of the sun from the water. As it is possible at small expense and with the exercise of intelligent care to stop the growth of algae by the use of sulphate of copper, and as the addition of a roof almost always adds very greatly to the cost of a reservoir, most reservoirs, and especially those of large capacity, are of the open type.

The designer having reached this point can now proceed with the details. From now on he will probably work on the cut-and-try plan, making preliminary sketches and estimates of many different types of design, and abandoning one after the other until convinced that he has finally selected the best one, all things considered, for the local conditions. In a recent case more than a score of such trial computations were made on as many different types of reservoir wall before the wall which seemed to meet most satisfactorily all of the requirements was selected.

SOME TYPICAL DESIGNS

Figure 1 shows in cross-section the wall and part of the bottom of a 2,000,000 gallon reservoir, 120 feet inside diameter, 19 feet 10 inches deep at the wall, and 24 feet 10 inches deep at the center. This reservoir was built partly in excavation and partly in embankment on clay soil. Its bottom, which was five inches thick, was reinforced throughout with steel sufficient only to resist temperature stresses. The reinforcement in the wall was continuous around the circumference, and was designed to resist the internal pressures just as the hoops on a barrel resist the internal pressures in the barrel.

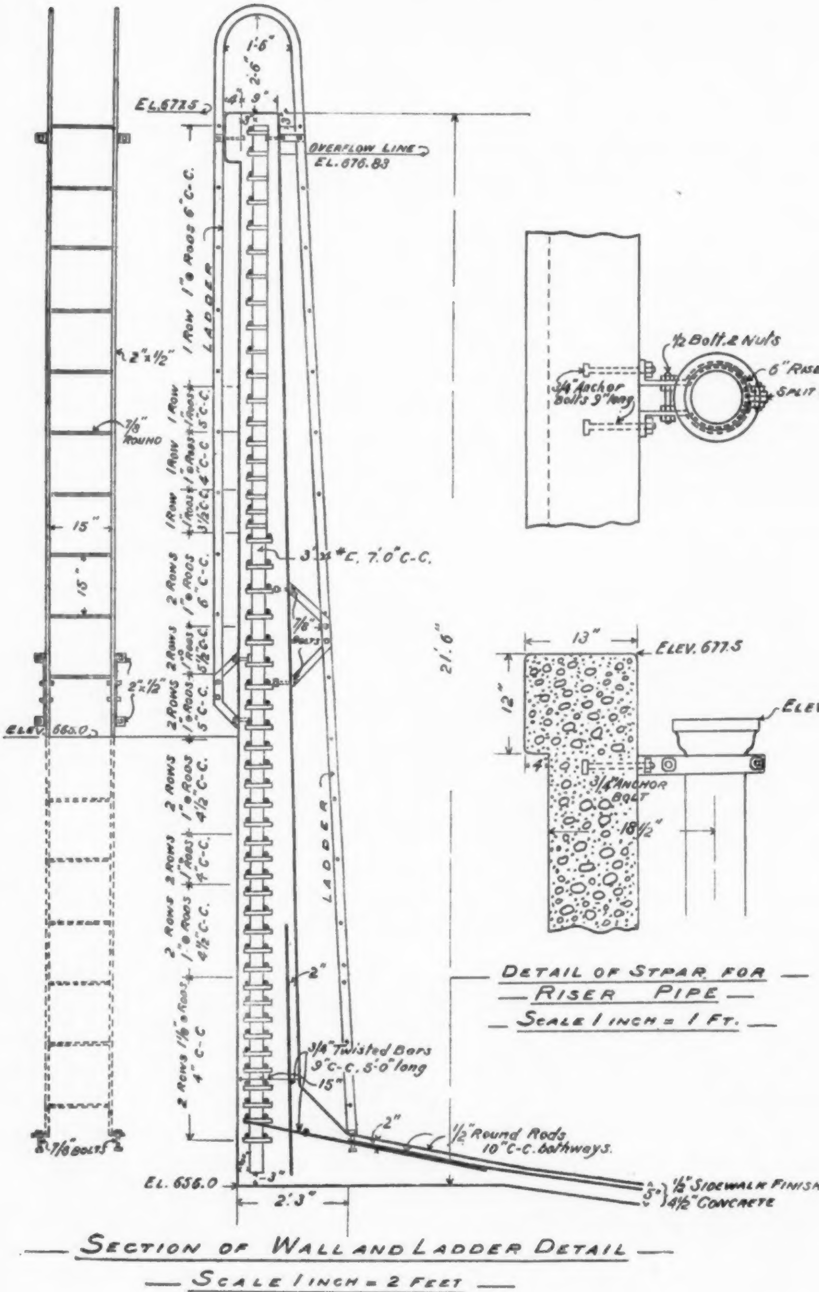


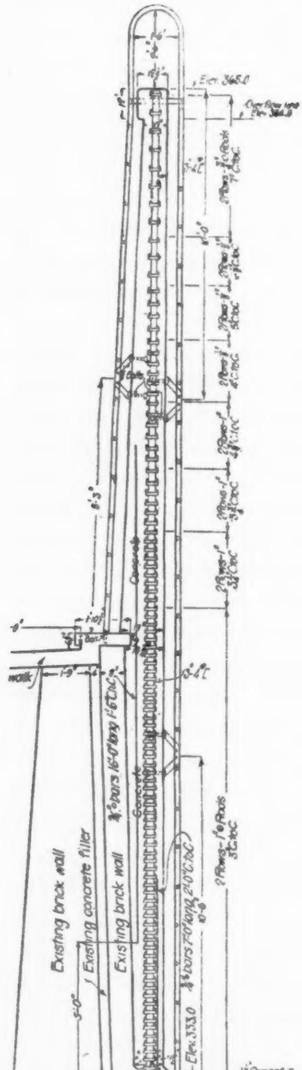
FIG. 1. WALL OF 2,000,000-GALLON RESERVOIR

Figure 2 shows in cross-section the wall of another reservoir in which the steel reinforcement was stressed as are the hoops in a barrel. This wall was built to enlarge the capacity of an existing reservoir by increasing its depth from 14 to 32 feet. The inside diameter of the reservoir, as enlarged, was 142 feet, and its capacity about 4,000,000 gallons. Right along side of this old reservoir was constructed a new one which was so designed that the part of it which showed above the finished grade should be an exact duplicate of the enlarged old reservoir, and figure 3 is a section through the wall of the new reservoir. Here again the reinforcing steel is subjected to hoop stresses.

Criticising his own work in the light of later experience, the writer would say that in designing the wall shown in figure 3 he made a mistake in putting all of the steel near the inner face of the wall and none of it very close to the outer face. The practical result of this was that in the cold weather which followed shortly after the construction of this reservoir, vertical cracks showed up in the outer surface of the wall all the way around at distances of 20 or 25 feet apart. These cracks were visible only near the bottom where the wall was thickest and where the bulk of the concrete lay outside of the reinforcing steel. None of them went through the wall, and no leakage resulted from these cracks, so that they did no harm except to cause some unnecessary alarm when they were first discovered. They are not now in evidence, as the earth embankment around the reservoir covers the lower fourteen feet of its height.

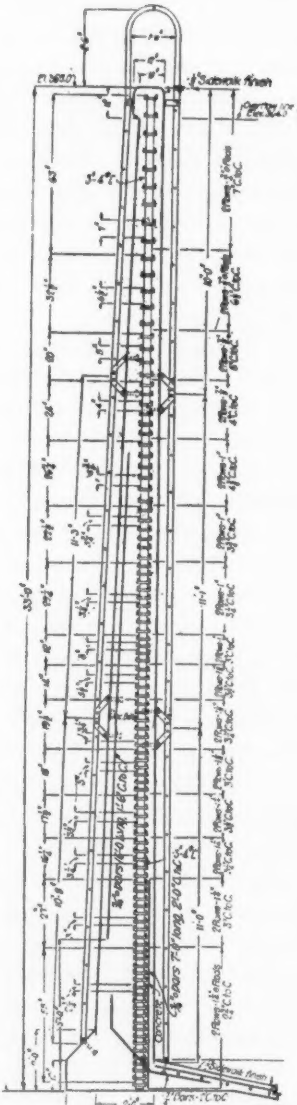
Figure 4 is a section through the wall of a reservoir of 10,000,000 gallons capacity. The diameter of this reservoir is 300 feet, and its depth at the wall 15 feet, and at the centre 25 feet. The bottom is reinforced throughout to resist temperature stresses, and the wall is designed as a cantilever gravity section, with only enough steel around the circumference to resist temperature stresses. This reservoir is believed to be the largest reinforced concrete reservoir ever built without expansion joints. It was built in 100 days, and was practically watertight when finished.

Figure 5 is a plan, and figure 6 a section through the wall of a 7,500,000 gallon reservoir build almost wholly in excavation, a considerable portion of the excavation being stratified limestone rock. The diameter of this reservoir was 180 feet, and its depth 42 feet. In this case the lower part of the wall was thin and was built solidly against the rock, while that portion of the wall above the rock was



WALL SECTION
OLD RESERVOIR

FIG. 2



WALL SECTION
NEW RESERVOIR

FIG. 3

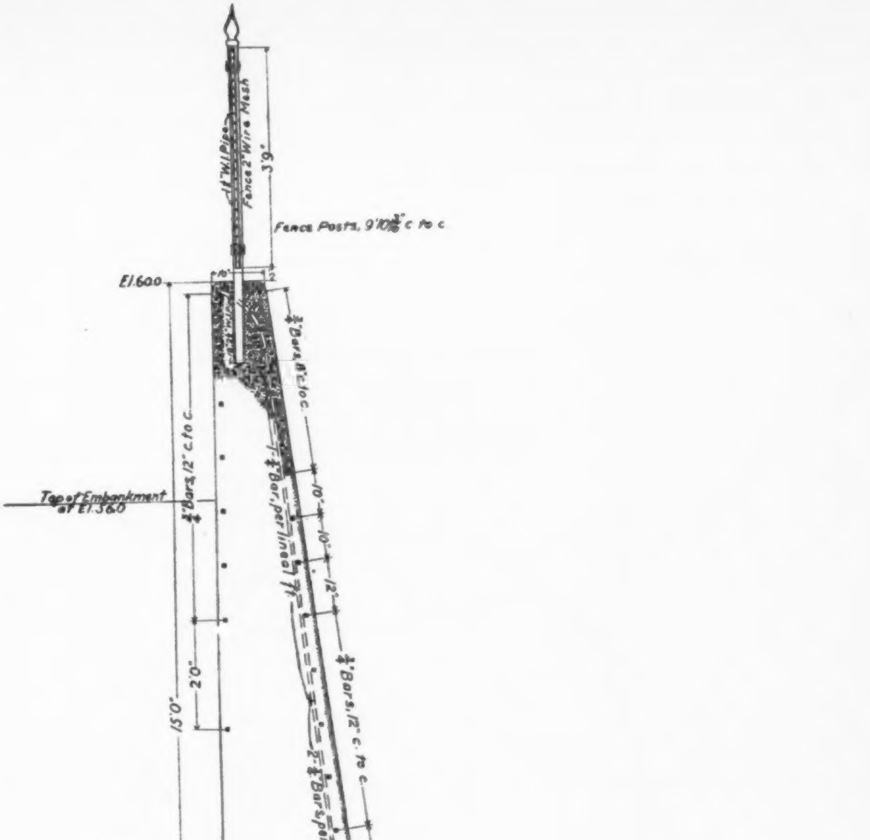


FIG. 4. WALL OF 10,000,000-GALLON RESERVOIR

constructed as a continuous slab supported by buttresses carried down to the rock, the height of the thick portion of the wall and the height of the buttresses varying with the elevation of the upper surface of the solid rock.

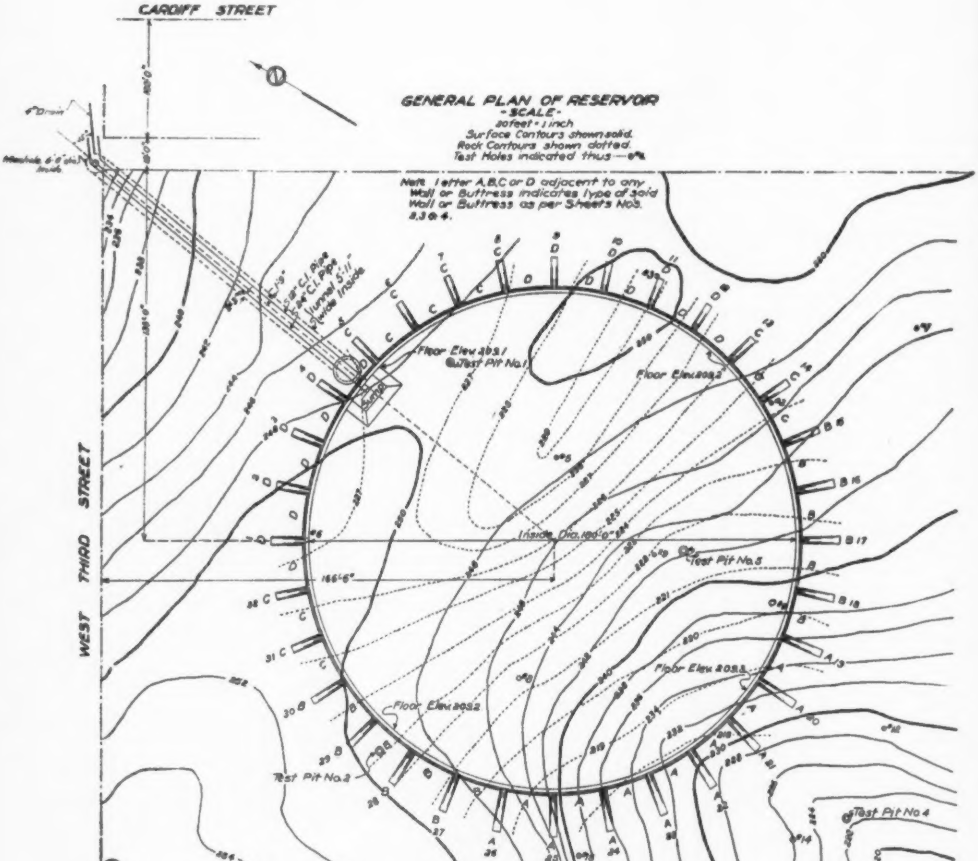


FIG. 5. PLAN OF 7,500,000-GALLON RESERVOIR

Figure 7 shows an entirely different type of reservoir, with beam and slab roof, slab walls and slab bottom for the bay next to the walls on each side, the remainder of the bottom being of the inverted groined arch type. This is not a distributing reservoir, but is in-

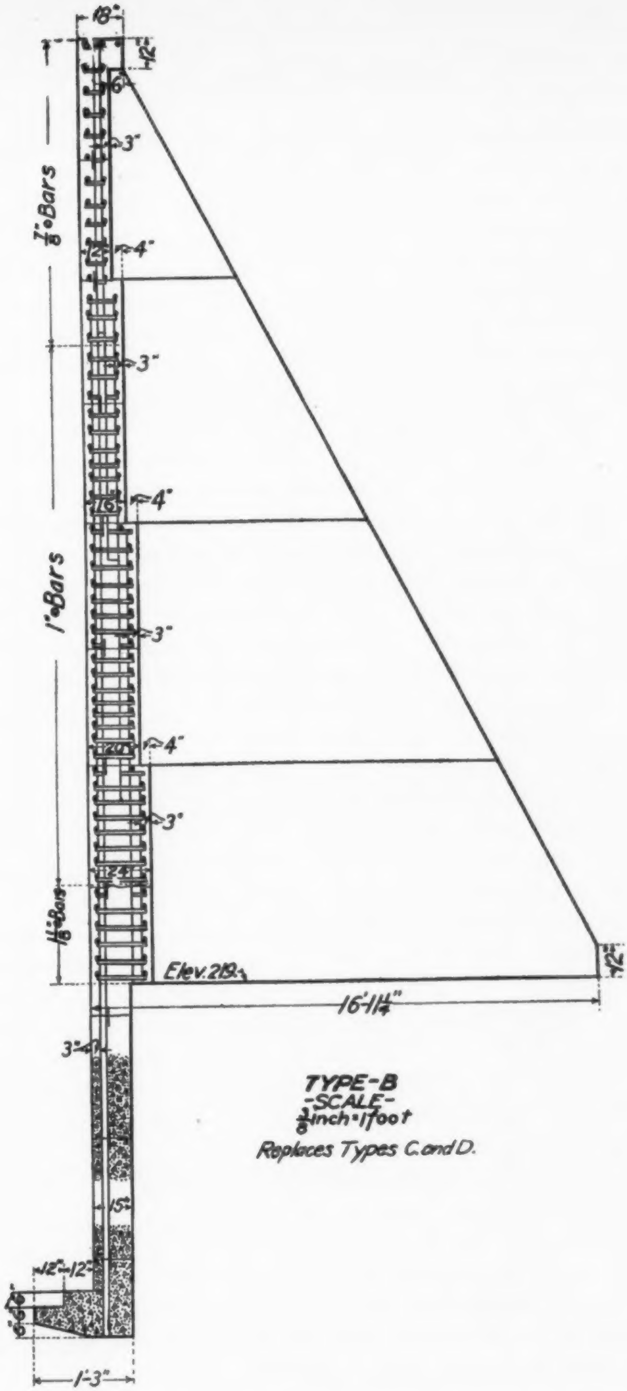


FIG. 6. WALL OF 7,500,000-GALLON RESERVOIR

tended to serve for the present as a storage reservoir for water pumped into it from distant wells. The reservoir is, however, so designed that later on its columns may serve as supports for an iron removal plant to be built on top of it, and it will then serve as a clear water reservoir. At times of very high water, the ground water, if it were unaffected by the pumping operations at the adjacent pumping station, would rise as high as the top of the reservoir, and if the reservoir were empty at such a time, the total upthrust would be greater than the weight of the reservoir and of its covering.

While it is not likely that there will ever be a time when the pumping operations at the station will cease for any long period, coincident with the pumping out of the reservoir itself, provision was nevertheless made to guard against any such contingency by sinking in each corner of the reservoir a 10 inch well equipped with a strainer of liberal area, having openings so large that they cannot become clogged by rust, and with a check valve opening into the reservoir. Should the ground water outside of the reservoir at any time rise higher than the water inside, these four wells will admit water to the reservoir with sufficient rapidity to prevent any danger from the unbalanced pressure of the ground water.

These wells were sunk before the construction of the reservoir was begun, and by pumping from them, the ground water, which would otherwise have stood several feet above the bottom of the reservoir, was held down below the bottom during the entire construction period, so that the whole structure was built in the dry.

A number of other reservoirs could be shown, but these six have been selected as representing more or less distinctive types. The wide variation in their design illustrates the effect of the local conditions and requirements in each particular case.

It will be noted that in the first three cases shown the reinforcing steel was stressed hoop-fashion, but that in the larger reservoirs of 10,000,000 and 7,500,000 gallons capacity, respectively, the hoop method was not used.

While no definite line can be drawn, it is thought that the 4,000,000 gallon reservoirs, which were 142 feet in diameter by 32 feet deep, were fairly close to the limit of size in which the hoop method of reinforcing could be economically employed. For capacities greater than these, the amount of steel required per vertical foot of wall becomes excessive, and usually some other type of wall will be found more economical for the larger reservoirs.

FIG. 7

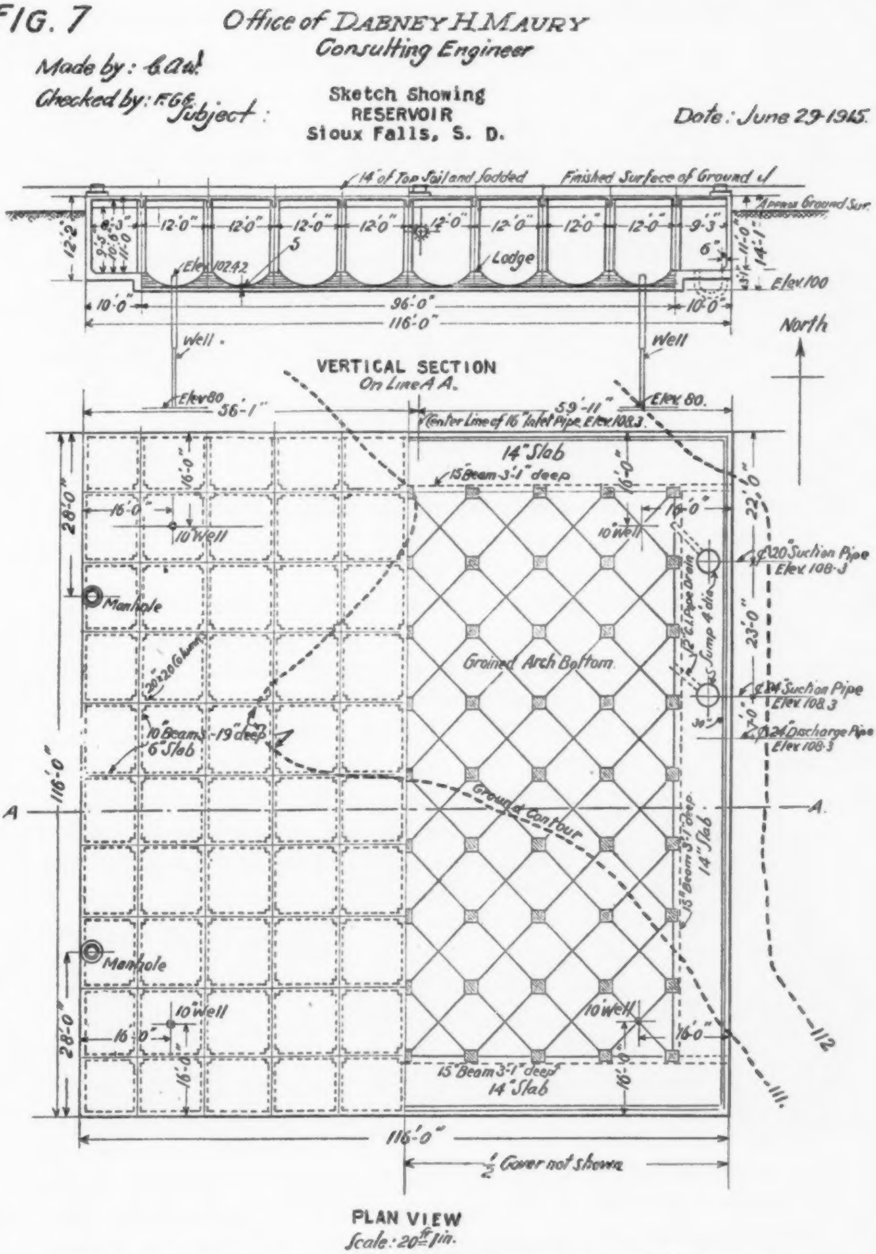


Fig. 7. Plan and Section of 1,200,000-Gallon Covered Reservoir

SOME CONSTRUCTION DIFFICULTIES AND SOME SUGGESTIONS

The first thing naturally demanded of a water works reservoir is that it shall hold water, and as a rule the most difficult part of the construction of a reservoir is making it watertight.

A small amount of leakage really does no great damage; but so long as any leakage can be detected, it is an eyesore, and it remains as a reproach to all of those in any way connected with the design or construction of the reservoir, whether contractor, engineer or owner. For these reasons, leaks so small that they could do not harm whatever are not as a rule permitted in the finished structure, even though the cost of stopping them is out of all proportion to the value of the water lost.

It was the writer's good fortune that in all of the reservoirs mentioned in this paper, he had to deal with contractors who endeavored honestly and conscientiously to secure good results. In almost every case they succeeded remarkably well, and when they failed, the failure was due to some oversight or bad judgment on their part, and not to any desire to skimp the work.

It is not an easy matter to build a reservoir which shall be absolutely watertight from the time the forms are removed. Fortunately, however, very small leaks will usually become less or "take up" in a short time, especially when the stored water contains iron or sediment, and in most cases it is not very difficult to stop large leaks or at least to reduce them to so small an amount that they will ultimately stop of themselves.

Figure 8 is a construction photograph of the 2,000,000 gallon reservoir already mentioned, and shows the bottom completed and the vertical channels for supporting the reinforcing bars already in place, with over half of these bars fastened to the channels. These channels served another useful purpose in that they afforded a convenient means of fastening the forms without having to run bolts or wires all through the concrete.

Figure 9 shows this same reservoir after it was finished and while it was under its initial test. The white streaks are ice formed by the freezing of the water which leaked from the reservoir. It will be noted that there were practically no leaks except at the construction joints or horizontal planes between the successive pourings of the concrete. Because of the formation of ice the leaks appear very much larger in this photograph than they actually were, for the total

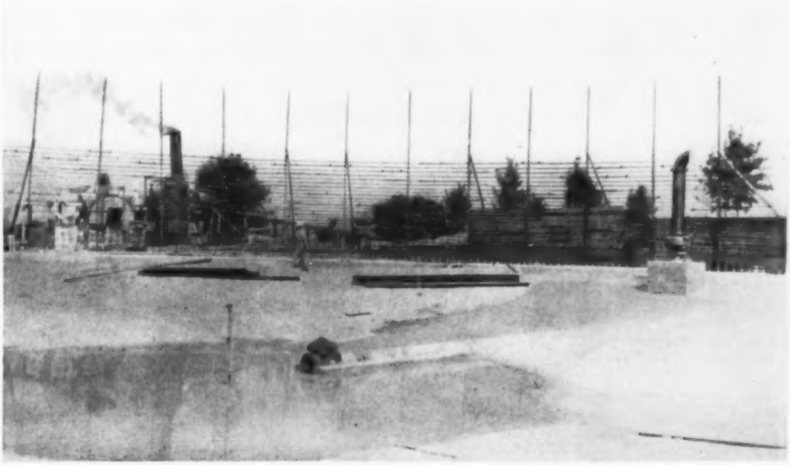


FIG. 8. 2,000,000-GALLON RESERVOIR DURING CONSTRUCTION

FIG. 9. 2,000,000-GALLON RESERVOIR AFTER FIRST TEST

leakage when the reservoir was first tested was not much over 3000 gallons per twenty-four hours. The contractor at first unwisely tried to stop the leaks by washing the inside of the reservoir, first with Sylvester mixture and then with cement. These coatings failed to adhere, and were of no value in stopping the leaks. No cracks of any sort could be detected in the reservoir even with the aid of a magnifying glass. The horizontal planes between successive pourings of concrete were plainly visible, and it was recommended that these be dug out in V-shaped grooves, running all around the reservoir, and having a depth of about $1\frac{1}{2}$ inches and a width of 1 inch at the surface, and that these grooves be carefully filled with a mixture of ironite and cement. This was done and the leakage was effectually stopped.

The construction of the 4,000,000 gallon reservoir, the wall of which was shown in figure 3, developed some surprising results. The enlargement to the old reservoir already shown in figure 2 was built by the same contractor who built the new reservoir shown in figure 3, the two jobs being parts of the same contract. The new reservoir was built first, and the enlargement to the old reservoir was made after the new reservoir had been put in service.

In this case, as in all of the others mentioned in this paper, the contractor was required to guarantee the watertightness of the finished work.

After the award of contract the writer discussed with the contractor the methods which he planned to employ in building the reservoir, and was informed that he intended to erect an elevator tower between the two reservoirs, construct the forms for the whole 32 feet in height of wall, and place his concrete in the wall by means of chutes, working day and night and pouring the concrete continuously until the entire wall was poured. The writer objected strongly to this method of construction, and spent much time in endeavoring to persuade him to abandon it, and to use removable forms not more than two or three feet in height, so that the concrete could be thoroughly spaded in place in the wall. Sketches of such forms were prepared, and estimates secured on steel forms which seemed to prove that they would be much cheaper than the wooden forms contemplated by the contractor. The contractor, however, argued that he had in stock a lot of lumber which could be used for forms and which he could so manipulate that it would suffer very little damage from such use. He further stated that he was afraid that

leaks would occur in the joints between successive pourings, and he claimed, with some justice, that so long as he was compelled to guarantee the final results, he was entitled to use any method of construction which he saw fit, provided the contract and specifications did not expressly forbid the use of that particular method. Finding himself unable to persuade or to compel the contractor to change his method of construction, the writer was obliged to allow the work to proceed.

In the meantime the contractor asked permission to use a cement with which the manufacturers mixed at the mill a certain alleged

FIG. 10. ERECTION OF FORMS AND STEEL WORK, 4,000,000-GALLON RESERVOIR

waterproofing material. This cement, so mixed, was subjected to the usual laboratory tests by one of the city engineers who had charge of the supervision of the construction work on the ground, and passed successfully all of the tests applied, complying with all of the requirements of the standard specifications of the Society for Testing Materials. Permission was accordingly granted to use this brand of cement, subject always to the provisions of the contractor's guarantee of the final results.

Figure 10 shows the erection of the channels, forms and reinforcing steel for the wall in progress.

Figure 11 shows the reinforcement in the bottom of the reservoir.

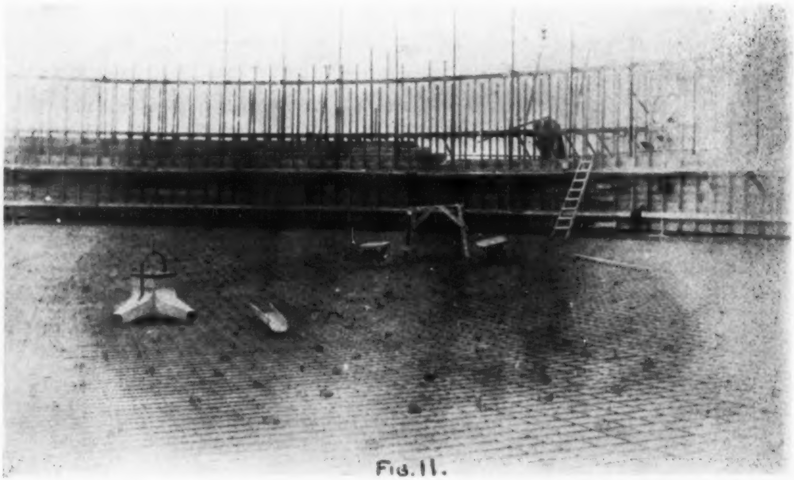


FIG. 11. CONSTRUCTION VIEW, 4,000,000-GALLON RESERVOIR, SHOWING REINFORCING STEEL IN FLOOR

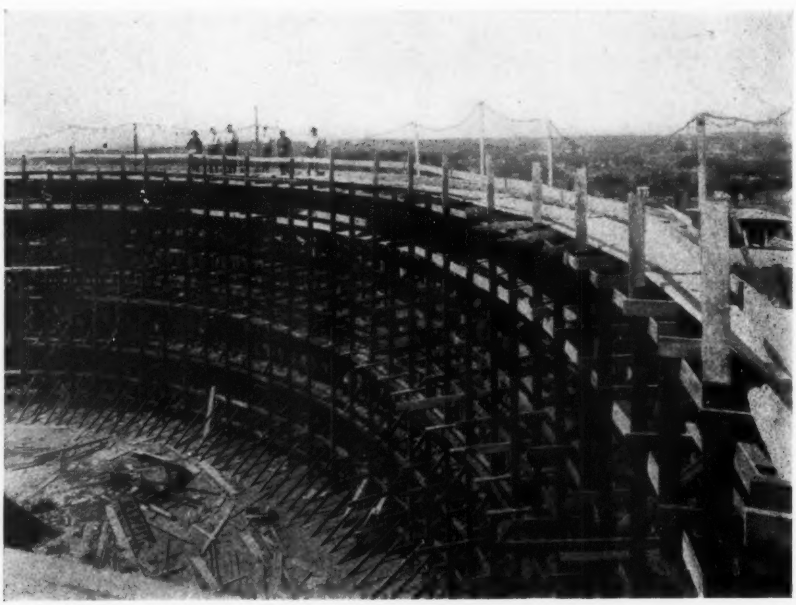


FIG. 12

Figure 12 shows the appearance of the structure after the reinforcing steel had all been placed in the wall, and the scaffolding for the wall forms had been practically completed.

Construction work proceeded rapidly, and it was evident that the contractor was doing all that could be expected of him to secure good results, but when the forms were removed, the entire surface of the wall was seen to be spotted with patches of a creamy or yellowish color. Investigation showed that wherever these patches occurred the material could be readily dug out of the wall with a pen knife, and this material contained no sand or stone, was almost as porous as a sponge or a piece of coral, and was so light that a

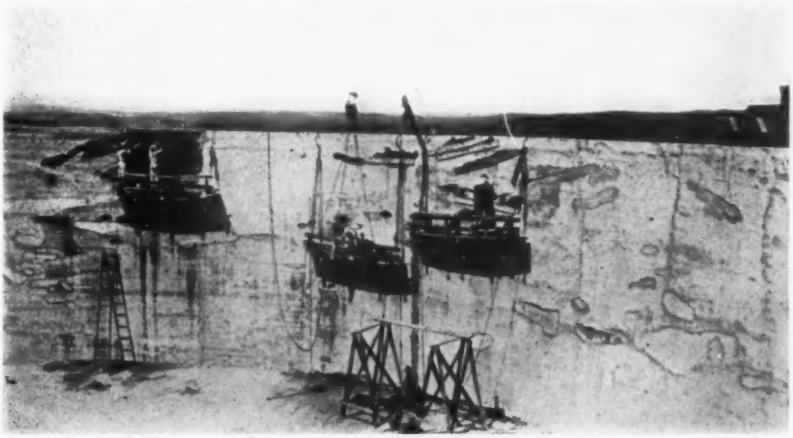


FIG. 13. CUTTING OUT SOFT SPOTS IN 4,000,000-GALLON RESERVOIR

lump of it would float in water. It was then evident that the so-called waterproofing mixture was of a soapy nature, and that when the concrete was poured down the chutes to its place in the wall, this soap formed a lather which separated from the stone and sand and from most of the cement, and lay on top of the rest of the ingredients. Just enough of cement appeared to remain in this lather to cause it to take a set.

Figure 13 shows the inside of the wall after the forms were removed, with some of the contractor's men cutting out the soft material and endeavoring to replace it with real concrete.

Figure 14 is another view of the same work. There were hundreds of these soft spots, most of which extended entirely through the wall,

the largest being about 25 feet long, by 3 or 4 feet deep. The contractor did his best to dig them all out and put good concrete in place of them, but as might be expected, the reservoir still leaked

Fig. 14. Cutting Out Soft Spots and Patching 4,000,000-Gallon Reservoir

Fig. 15. The Completed Reservoir

after this had been done. When all of the soft spots had been dug out, and before the holes had been refilled with concrete, the structure resembled a gigantic bird cage as much as it did a reservoir; and it would have served almost as well for the one as for the other.

It was finally necessary to put in a membrane lining of waterproofing material over the wall and bottom, and to cover this with a protecting coat of several inches of reinforced concrete. This produced a watertight reservoir.

In the construction of the enlargement to the old reservoir, it is needless to say that the contractor did not pour all of the wall at one pouring, and that he did not use the socalled waterproofing substance. When the forms were removed from the second piece of work there were a very few small leaks which either stopped themselves in a short time, or were stopped without much difficulty.

Figure 15 shows the two reservoirs as finally completed and in service.

Figure 16 is a photograph taken during the construction of the 10,000,000 gallon reservoir, the wall of which was shown in figure 4.

Notwithstanding the fact that the price which the contractor for this reservoir received yielded him no profit whatever on the job, he spared no expense to make his work first class in every particular, and he succeeded in this respect better perhaps than the contractors for any of the other reservoirs herein described. The photograph shows the wall of the reservoir completed, while the grading outfit is still engaged in removing the dirt from the center. Most of the excavation was done with a Page bucket, or dragline scraper.

After the forms were removed from the wall the space between the embankment and its outer surface was filled with water to test the wall for leakage. The inner surface of this wall was 942 feet long by 15 feet high, and in this entire area there were but three spots which showed any dampness. From one of these there was a small trickle amounting to only a few drops per minute.

There were no spots on the entire inner surface where stone showed against the forms, and this result was largely due to a device for which the contractor should be given credit. In building the wall a portable plate of thin metal was held at all times about $\frac{3}{4}$ inch away from the inner form, and as each batch of concrete was poured behind this plate, one-to-one cement mortar was poured in front of the plate and between it and the inside form, in quantities sufficient to keep the upper surface of the mortar level with the upper surface of the last batch of concrete. These plates were moved ahead as the pouring progressed around the circumference, being from time to time drawn up so that the mortar in front of them could unite thoroughly with the concrete behind them before either

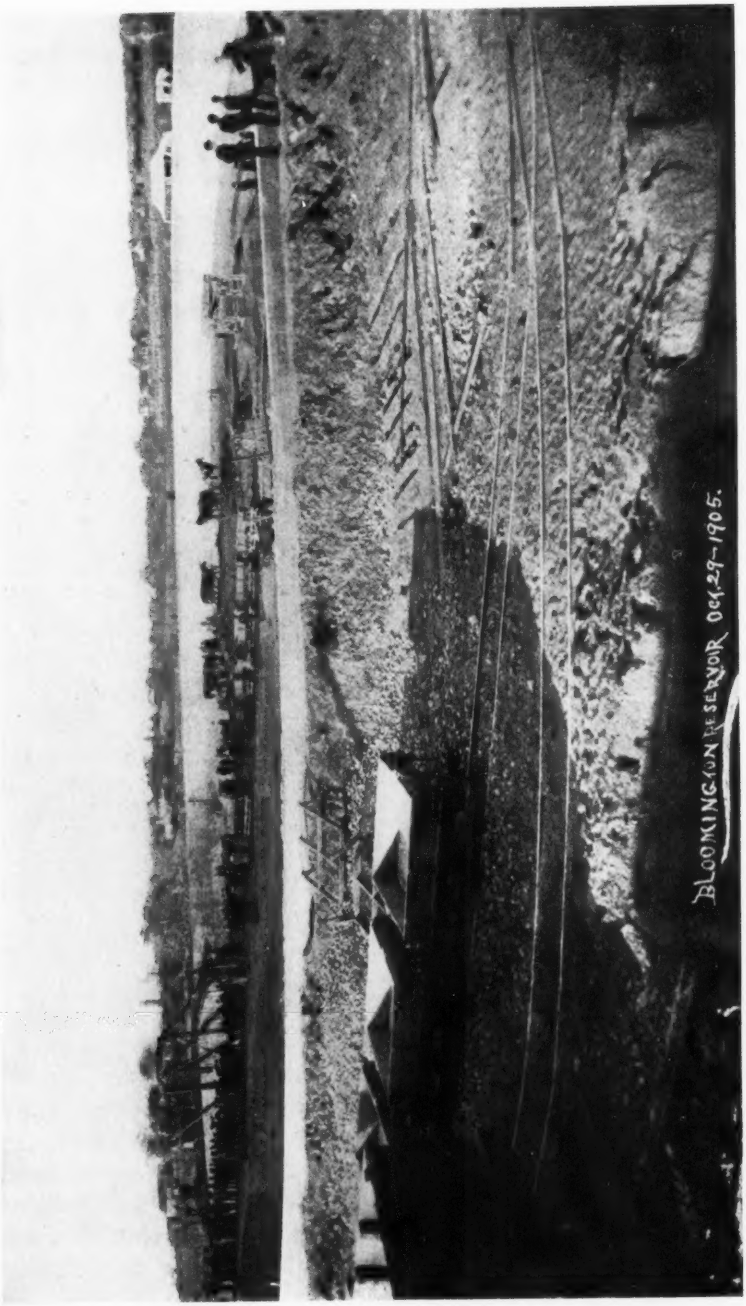


FIG. 16

had time to begin to set. The excellent results obtained in this work were due in part to this device of the contractor, and in part to the conscientious thoroughness which characterized all the rest of his work.

Figure 17 shows the excavation for the 7,500,000 gallon reservoir, the design of which was shown by figures 5 and 6.

Figure 18 shows the placing of the supports for the reinforcing steel.

Figure 19 shows the reservoir about half completed, and figure 20 is a view of the completed reservoir and gate house, taken before the

FIG. 17. EXCAVATION, SHOWING CLAY ABOVE AND STRATIFIED ROCK BELOW

grading had been finished and before the ornamental fence designed to protect the reservoir against pollution had been erected.

When this reservoir was finished and tested by filling the space between the outside of its wall and the surrounding earth with water, a number of spots showed on the inside, and there were two or three small streams which spurted out from the inner surface of the wall. When the reservoir was filled and the loss of water measured with a gauge, it was found that this amounted to about 32,000 gallons in twenty four hours, of which a very small part was due to evaporation. The wall of this reservoir was poured in 4 foot layers, and steel dams 8 inches high and $\frac{1}{8}$ inch thick were provided at each construction joint for the purpose of minimizing the tendency to

leakage at these joints. Incidentally, these dams, which were bolted to the vertical channels, assisted materially in the erection of the channels. There was only one leak of any size at a construction joint, and at this spot the surface of the joint had been covered by a

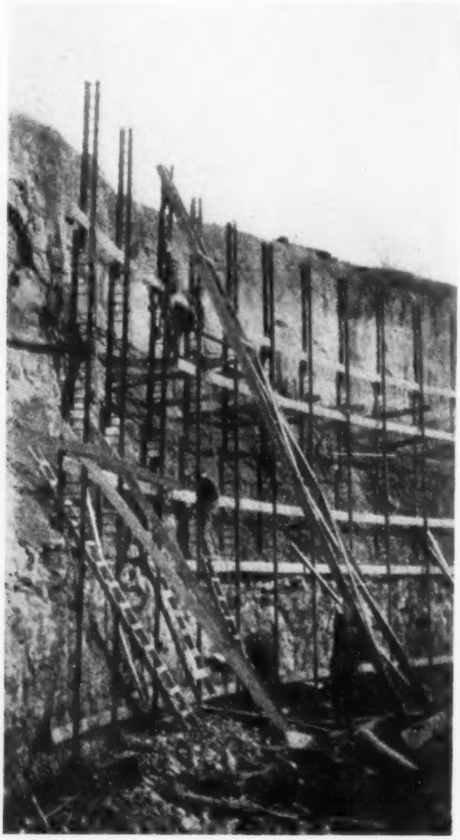


FIG. 18. PLACING SUPPORTS FOR REINFORCING STEEL

fall of clay from the bank above, and the contractor had evidently failed to remove all of this clay.

The specifications for this reservoir, as well as those for other more recent ones, called for the use of a vacuum cleaner for cleaning the surface of concrete already poured before fresh concrete should be poured on top of it. The work was not, however, supervised by the

Fig. 19. Reservoir Half Completed

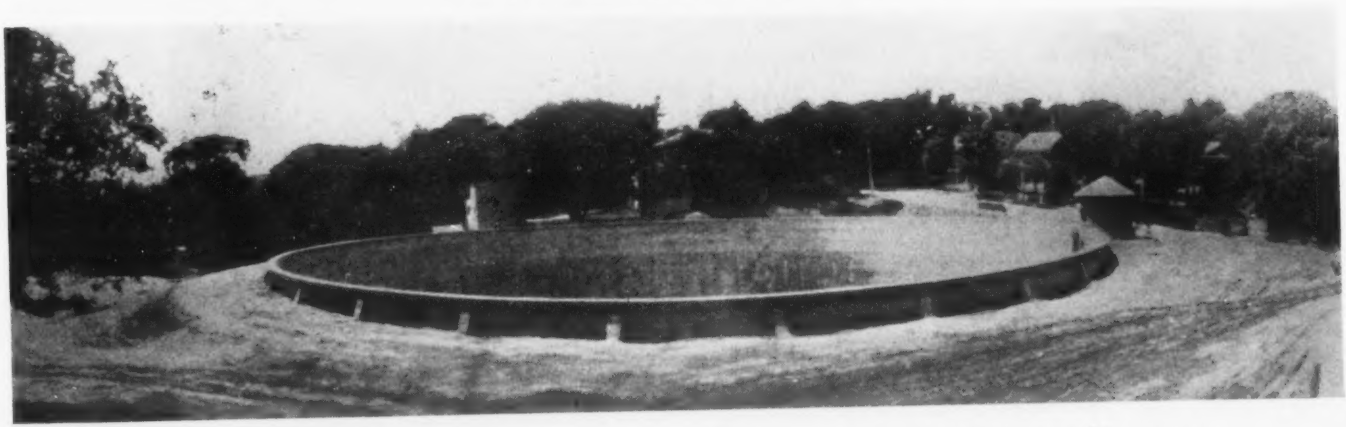


Fig. 20. 7,500,000-Gallon Reservoir Complete, Except for Grading, Turfing and Fencing

writer, and this provision was not carried out, the contractor simply brushing the joints in the usual manner before pouring the next

FIG. 21. CONSTRUCTION VIEW, COVERED RESERVOIR

batch of concrete. This brushing of the joints cannot give the best results for the reason that the dust and rubbish and laitance are

simply moved from one part of the surface to another, whereas if a vacuum cleaner were used they could be removed entirely.

Fig. 22. Portable Steel Frame for Molding Ground Arches

Fig. 23. Portable Steel Frame and Some Completed Arches

Figure 21 is a construction photograph of the 1,200,000 gallon covered reservoir already shown by figure 7. Attention is called to

the unusually careful and accurate manner in which the contractor for this work placed his reinforcing steel, the correct alignment of which shows very plainly in the photograph. This contractor also devised and used with great success a steel frame or templet for building the groined arches. These frames were so light that they could readily be moved from place to place, and the foundations for each column, instead of being built in four pieces, as is usually the case in this type of construction, were built in one piece, the concrete being simply piled up and tamped inside of the frame and smoothed off with a screen which was passed along the upper surface of the corner angles of the frame. The groins were then given a trowel finish. One of these frames is shown in figure 22, and another in figure 23, which also shows a number of the completed groined arches.

Figure 24 is an interior view looking down one bay of the completed reservoir, and showing the columns with the groined arches at the bottom, and the beam and slab roof at the top.

The workmanship on this reservoir was unusually good, the only defects being a few rough spots, which were promptly corrected by the contractor.

As a result of his experience with these and with a number of other concrete reservoirs, the writer would draw the following conclusions:

1. It is entirely possible with proper materials, mixture and workmanship to prevent moisture from passing through a concrete wall a foot thick even under fairly heavy pressures.

2. It is not to be expected, however, that the perfection of workmanship required to produce these results will always be obtained at every single point over an area of thousands of square feet of wall.

3. Such leaks as may show in spite of conscientious efforts to do good work can almost invariably be stopped entirely or be reduced to such a point that they will stop themselves in the course of time, especially if the water carries iron or sediment.

4. Leaks are most likely to occur at construction joints. The use of steel dams will reduce the danger of such leaks, but these dams cannot always be relied upon to prevent the leakage, and their presence should not be allowed to diminish in any way the precautions which should always be taken to prevent leakage at the joints.

5. The surface of concrete which has begun to set should be scratched and roughened, and all dust, rubbish and laitance should be carefully removed with a vacuum cleaner before the next batch of

concrete is poured. This will not always prevent leakage, but it will go far towards doing so.

FIG. 24. INTERIOR VIEW OF COVERED RESERVOIR

6. In reservoir construction the use of chutes for conveying concrete to its place in the wall should not be permitted unless the con-

crete is thoroughly remixed just before it reaches its final place in the wall.

7. While good results can be obtained by very careful spading of the concrete adjacent to the forms, so as to keep the stone away from the inner surface of the wall, it is believed that far better results would be secured by the plan devised by the contractor for the 10,000,000 gallon reservoir already described; namely, the use of a portable sheet of thin metal with means for holding it about $\frac{3}{4}$ inch away from the inner form, the concrete to be poured back of this sheet of metal, and cement mortar in front of it and between it and the form.

THE SECTIONS

NEW YORK

A meeting of the Governing Board of the New York Section was held March 15, 1916, at which time the following were elected for the ensuing year:

Chairman, Mr. Allen Hazen.

Secretary, Mr. William W. Brush.

CANADA

A petition for the formation of a Canada Section has been submitted to the Executive Committee of the Association and favorably acted upon. No official meeting of the Section has yet been held.